

Collaboratory for the Study of Earthquake Predictability

(Probabilistic Estimates of
Network Recording Completeness)

D. Schorlemmer (SCEC/USC)

Contributions from:

T. Jordan, M. Liukis, P. Maechling, J. Yu, J. Zechar (SCEC/USC)
J. Woessner, F. Euchner, S. Wiemer, C. Bachmann, E. Kissling, K. Nanjo (ETH)
F. Mele, W. Marzocchi, M. Cocco (INGV)
M. Gerstenberger (GNS)
D. Oppenheimer (USGS)

Collaboratory for the Study of Earthquake Predictability (CSEP)

... is an open, international partnership to support a global program of research on earthquake predictability through prospective, comparative testing of scientific prediction hypotheses in a variety of tectonic environments.

Three Definitions

- Earthquake predictability
 - degree to which the future occurrence of earthquakes is encoded in the behavior of an active fault system
- Scientific earthquake prediction
 - a testable hypothesis, usually stated in probabilistic terms, of the location, time, and size (and perhaps other parameters) of fault ruptures
- Useful earthquake prediction
 - advance warning of potentially destructive fault rupture precise and reliable enough to warrant actions to prepare communities

Three Questions

Q1 How should scientific earthquake predictions be stated and tested?



- How should prediction experiments be conducted and evaluated?

Q2 What is the intrinsic predictability of the earthquake rupture process?



- What could we predict if we understood more about earthquake physics?

Q3 Can knowledge of large-earthquake predictability be deployed as useful predictions?

- Is operational earthquake prediction feasible?

“Silver Bullet” Approach

- Seeks useful, short-term prediction of large earthquakes; i.e., focuses on direct answer to **Q3**
 - “heroic quest” for a simple solution
 - dominated research in the 1970’s and 1980’s
- Searches for signals diagnostic of approach to rupture, including:
 - foreshocks
 - strain-rate changes
 - electromagnetic signals
 - hydrologic changes
 - geochemical signals
 - animal behavior
- Has not thus far led to useful prediction methodologies



Problems in Assessing Predictions

- Scientific publications provide insufficient information for independent evaluation
- Active researchers are constantly tweaking their procedures, which become moving targets
- Difficult to find resources to conduct and evaluate long-term prediction experiments
- Data to evaluate prediction experiments are often improperly specified
- Standards are lacking for testing predictions against reference forecasts

CSEP Goals

1. Reduce the controversy surrounding earthquake prediction through a collaboratory infrastructure to support a wide range of scientific prediction experiments
2. Promote rigorous research on earthquake predictability through the SCEC program and its global partnerships
3. Help the responsible government agencies assess the feasibility of earthquake prediction and the performance of proposed prediction algorithms

“Brick-by-Brick” Approach

- Focused on experimentation (Q1) and predictability (Q2), not operational and useful prediction (Q3)
 - Long-term effort to understand and improve predictability, even if probability gains are small
- Demonstrates predictability by rigorous testing based on *intercomparison* of models
 - RELM program and its extension to a Collaboratory for the Study of Earthquake Predictability (CSEP)

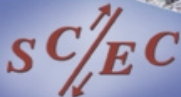


CSEP Design

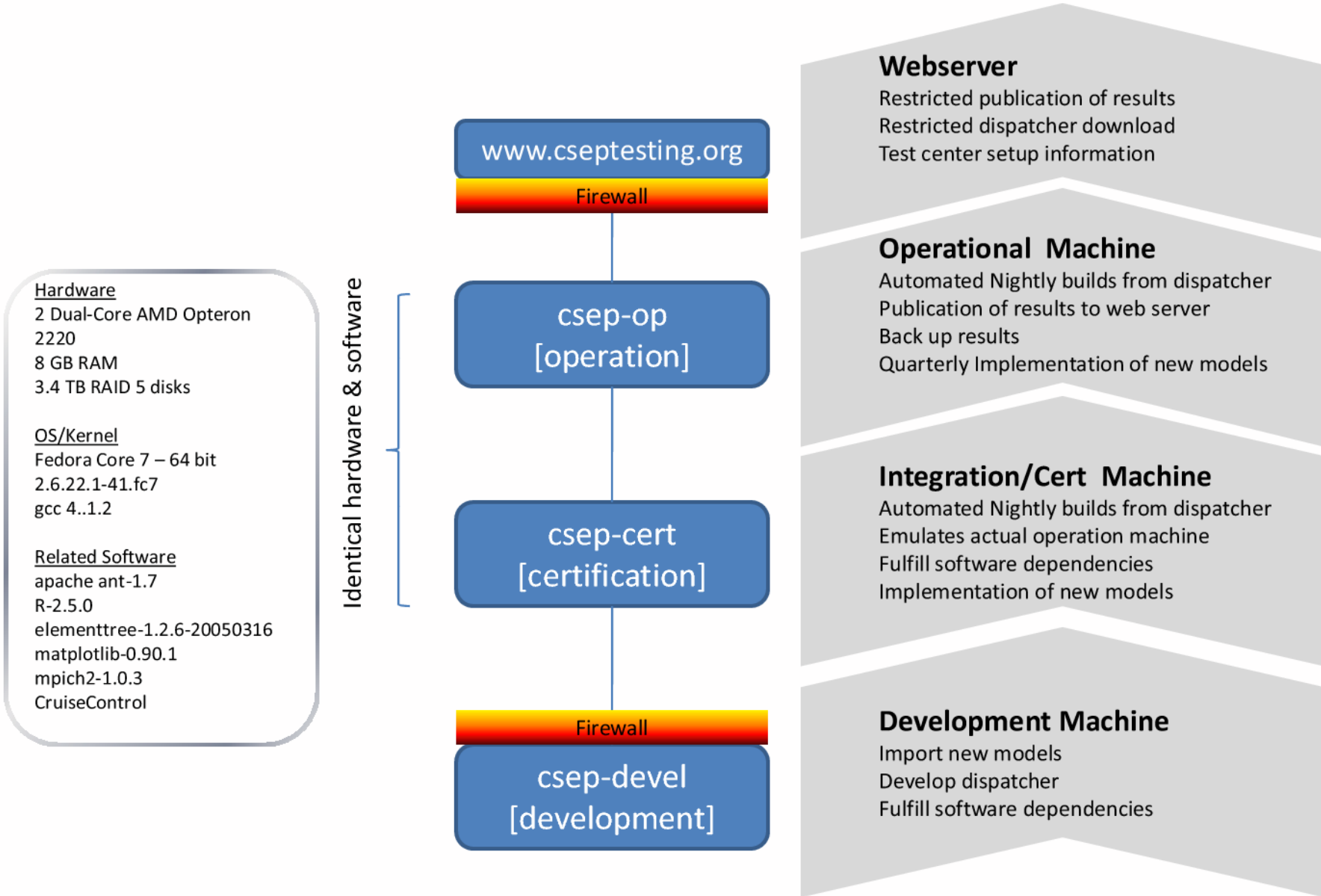
- Objective is to provide trustworthy answers to two questions
 - How was the earthquake prediction produced?
 - How was the earthquake prediction evaluated?
- Design goals
 - Data streams must be *authorized* and *calibrated*
 - Environment must be *controlled* and *transparent*
 - Results must be *reproducible* and *comparable*

Four Essential CSEP Components

- **Testing centers:** facilities with validated procedures for conducting and evaluating prediction experiments
- **Community standards:** rules for the registration and evaluation of scientific prediction experiments
- **Communication protocols:** procedures for conveying scientific results and their significance
 - the scientific community, including professional societies
 - government agencies responsible for risk management
 - the general public and other end-users
- **Testing regions:** active fault systems with adequate, authorized data sources for conducting prediction experiments



Testing Center



Web Collaboration System



logged in as liukis | [Logout](#) | [Settings](#) | [Help/Guide](#) | [About Trac](#)

	Wiki	Timeline	Roadmap	Browse Source	View Tickets	New Ticket	Search
	Available Reports Custom Query						

{6} All Tickets By Milestone (Including closed) (70 matches)

A more complex example to show how to make advanced reports.

[Edit report](#) [Copy report](#) [Delete report](#)

Basic Test Center - Version 8.4

Ticket	Summary	Component	Status	Resolution	Version	Type	Priority	Owner	Modified
# 3	Install Yan's one-day model on motion.usc.edu	NaturalLaboratory	new	None	1.0	task	major	somebody	05/29/07
# 4	Set up Yan' model one-day test scenario	NaturalLaboratory	new	None	1.0	task	major	somebody	05/29/07
# 14	Distribution of codes	Toolkit	assigned	None	1.0	task	major	liukis	01/08/08
# 15	Example data formats	DataTypes	new	None	1.0	task	major	somebody	05/10/07
# 16	Code documentation	Documentation	new	None	2.0	task	major	somebody	09/04/07
# 21	CSEP Testing Center Policy report	Documentation	new	None	2.0	task	major	somebody	09/19/07
# 22	Create form letter response	Documentation	new	None	1.0	task	major	somebody	05/29/07
# 26	Results reproducibility exercise.	Toolkit	assigned	None	1.0	task	major	liukis	08/30/07
# 36	Re-implement RELM evaluation N-test in Python without the use of random numbers	Toolkit	assigned	None	2.0	task	major	liukis	01/24/08
# 38	Generate CSEP Testing Center Technical report	Documentation	new	None	2.0	task	major	somebody	09/19/07
# 40	Archive yum updates and develop policy for updating csep_operational	Documentation	new	None	2.0	task	major	somebody	09/19/07
# 42	Setup matlab stand alone license manager	Toolkit	new	None	2.0	task	major	somebody	09/19/07
# 44	Describe techniques for checking evaluation algorithms	Documentation	new	None	2.0	task	major	somebody	09/19/07
# 45	Setup monitoring system (such as big brother) for csep_operational	NaturalLaboratory	new	None	2.0	task	major	somebody	09/19/07
# 47	Install Max Werner's one-day ETAS model	NaturalLaboratory	new	None	2.0	task	major	somebody	09/19/07
# 49	Look at possibility of making dispatcher runs completely independent.	Toolkit	assigned	None	2.0	enhancement	major	liukis	10/29/07
# 50	Display image of the forecast on result web-page		new	None	2.0	enhancement	major	somebody	09/24/07
# 51	Consider rewriting/invoking Fortran declustering code in Python	Toolkit	new	None	2.0	task	major	somebody	09/24/07
# 52	Construct csep_operational disk transfer verification and disk cleanup	Hardware	new	None	2.0	task	major	somebody	09/25/07
# 58	Add unit test to exercise pre-processing of ANSS catalog data and passing that data to forecast model	NaturalLaboratory	new	None	2.0	task	major	somebody	11/08/07
# 59	Add encryption to the email account password used by Dispatcher	DataTypes	new	None	2.0	enhancement	major	somebody	11/29/07
# 60	Investigate increasing of the Matlab recursive limit for STEP one-day model	NaturalLaboratory	new	None	2.0	defect	major	somebody	11/30/07
# 63	Test rates that were processed with V1.0 should be reprocessed with V8.1	NaturalLaboratory	assigned	None		task	major	liukis	01/14/08
# 64	Add GMT authorized data source	Toolkit	assigned	None		task	major	liukis	01/15/08
# 66	Re-implement RELM evaluation L-test in Python without the use of random numbers	Toolkit	new	None		enhancement	major	somebody	01/24/08
# 67	Re-implement RELM evaluation R-test in Python without the use of random numbers	Toolkit	new	None		enhancement	major	somebody	01/24/08
# 68	Adopt QuakeML format for catalog data	Toolkit	new	None		task	major	somebody	01/24/08
# 43	Setup automated retries for ANSS catalog data access	Toolkit	new	None	2.0	enhancement	minor	somebody	09/25/07
# 65	Create metadata file for each newly generated forecast file	Toolkit	closed	fixed		task	major	liukis	02/01/08
# 41	Setup a copy of all daily results needed for reproducibility to USC HPCC account	Hardware	closed	fixed	2.0	task	major	somebody	02/01/08
# 69	Don't invoke archive and ssh commands for result publishing if no evaluation tests have been invoked	Toolkit	closed	fixed		defect	major	liukis	01/29/08
# 55	Post warning notice about ANSS events used by SCEC testing center V1.0	NaturalLaboratory	closed	invalid	2.0	task	major	somebody	01/17/08
# 62	File IO approach used by Python random number generator doubles up the processing time	Toolkit	closed	fixed		defect	major	liukis	01/17/08
# 61	getCatalog_Import.m cannot import over 1 million of catalog events	Toolkit	closed	fixed		defect	major	liukis	01/15/08



continuous integration toolkit

Project

CSEP

waiting for next time to build since

02/01/2008 15:08:25

Latest Build

02/01/2008 09:30:17 (build.96)

02/01/2008 00:00:28

01/28/2008 00:00:07 (build.95)

01/27/2008 00:00:34 (build.94)

01/26/2008 00:00:40 (build.93)

RSS

Build Results

Test Results

XML Log File

Metrics

Control Panel

BUILD COMPLETE - build.96

Date of build:

02/01/2008 09:30:17

Time to build:

338 minutes 2 seconds

Last changed:

02/01/2008 09:19:06

Last log entry:

Added missing import of Forecast module

[Build Artifacts](#)

Errors/Warnings: (1)

Confirm that ResultsCumulativeSummary.py module generates and updates evaluation L-test cumulative results file properly. ... ok

Confirm that ResultsCumulativeSummary.py module generates and updates evaluation N-test cumulative results file properly. ... ok

Confirm that ResultsCumulativeSummary.py module generates and updates evaluation R-test cumulative results file properly. ... ok

Confirm that catalog data is out to the geographical area. ... ok

Confirm that Dispatcher writes values properly. ... ok

Confirm that exception is raised if configuration file does not exist. ... ok

Confirm that exception is raised if configuration file does not specify any forecast group directories. ... ok

Confirm that exception is raised if configuration file does not specify top level directory. ... ok

Confirm that ForecastGroup identifies existing forecast files properly. ... ok

Confirm that ForecastGroup properly parses initialization file. ... ok

Confirm that XML format forecast template is working properly. ... ok

Confirm that ResultsSummary.py module generates and updates evaluation L-test cumulative results file properly. ... ok

Confirm that ResultsSummary.py module generates and updates evaluation N-test cumulative results file properly. ... ok

Confirm that ResultsSummary.py module generates and updates evaluation R-test cumulative results file properly. ... ok

Confirm that plotting routines based on XML format result data are generating svg files. ... ok

Confirm that plotting routines based on XML format summary result data are generating svg files. There are intermediate and cumulative summary results. ... ok

Confirm that Dispatcher publishes results plots to remote host (localhost) with passwordless connection is used in the test). ... ok

Confirm that Dispatcher does not attempt to publish results plots to remote host if no such plot files were generated by the run. ... ok

Confirm that R-test produces the same result asymptotically (R12 = -R21). ... ok

Confirm that independence probability is randomized according to the rules. ... ok

Ran 20 tests in 75.506s

OK

Test post-processing of undeclassified catalog for short-term forecast generation, and succeed. ... ok

Test post processing of undeclassified catalog for short-term forecast evaluation as well as catalog uncertainties, and succeed. ... ok

Test post-processing of undeclassified catalog for long-term forecast evaluation. ... ok

Test declassified catalog post-processing for long-term forecast evaluation, as well as catalog uncertainties, and succeed. ... ok

Test post-processing of catalog for three-months forecast generation, and succeed. ... ok

Test post-processing of catalog for three-months forecast evaluation, and succeed. ... ok

Test pre-processing of raw catalog data and succeed. (the result catalog is in so-called ZMAP-format). ... ok

Test import of over one million events into Matlab format (the result catalog is in so-called ZMAP-format). ... ok

Test retrieval of raw ANSS catalog data and succeed. Download data for the previous month with default start date of 1585-1-1 and check for non-empty raw and pre-processed catalog file. ... ok

Test retrieval of raw ANSS catalog data and succeed. Download data for the previous month with start date other than default (1932-1-1) and check for non-empty raw and pre-processed catalog file. ... ok

Run L-test for the short-term forecast evaluation and succeed. ... ok

Run N-test for the short-term forecast evaluation and succeed. ... ok

Run L-test for the long-term forecast evaluation and succeed. ... ok

Run N-test for the long-term forecast evaluation and succeed. ... ok

Run R-test for the long-term forecast evaluation and succeed. ... ok

Run L-test for the three-months forecast evaluation and succeed. ... ok

Run N-test for the three-months forecast evaluation and succeed. ... ok

Run R-test for the three-months forecast evaluation and succeed. ... ok

Generate EEPAS OR forecast and succeed. ... ok

Generate PPF and EEPAS-IR forecasts for Southern California testing region, combine with forecasts for the whole testing region of California and succeed. ... ok

Generate EEPAS-IF forecast and succeed. ... ok

Generate EEPAS-IR forecast and succeed. ... ok

Generate EIAS forecast and succeed. ... Read 926 items

Read 11 items

Read 210706 items

Read 12 items

There were 50 or more warnings (use warnings() to see the first 50)

ok

Generate STEP forecast and succeed. ... ok

Run L-test for the short-term forecast evaluation (draw random numbers by the system). ... ok

Run N-test for the short-term forecast evaluation (draw random numbers by the system). ... ok

Run L-test for the long-term forecast evaluation (draw random numbers by the system). ... ok

Run N-test for the long-term forecast evaluation (draw random numbers by the system). ... ok

Run R-test for the long-term forecast evaluation (draw random numbers by the system). ... ok

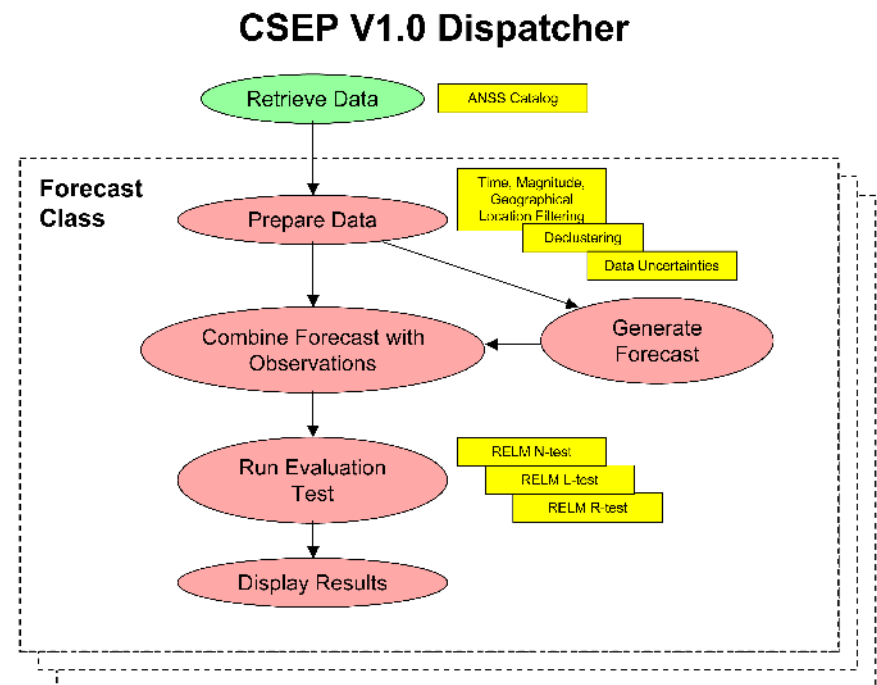
Run L-test for the three-months forecast evaluation (draw random numbers by the system). ... ok

Run N-test for the three-months forecast evaluation (draw random numbers by the system). ... ok

Run R-test for the three-months forecast evaluation (draw random numbers by the system). ... ok

CSEP Testing Center Software

- Daily Automated Earthquake Forecast Generation
 - STEP, ETAS forecast models
- Automated Earthquake Forecast Evaluation
 - RELM N , L and R tests
- Automated Testing Framework
 - Acceptance tests
- Reproducibility of Results
 - Software version control
 - System configuration archive
 - Data set archive
- Identical Integration and Operational Systems
 - Common, standardized open-source software stack



Milestones

1 September 2007

- Release of CSEP Testing Center Software 1.0
- Operational system up and running
- 19 RELM 5-year models under test

1 January 2008

- Release of CSEP Testing Center Software 8.1
- First 1-day and 3-month models under test
- New Zealand operational and manually testing
- Europe operational

1 April 2008

- Release CSEP Testing Center Software 8.4
- Optimizations

1 July 2008

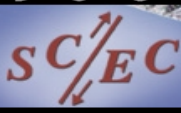
- Release CSEP Testing Center Software 8.7
- Western Pacific testing

Worldwide Collaboration

- Main development
- CSEP software maintainer
- Web development

- QuakeML
- QuakePy
- Visualization

- QuakeML webservice

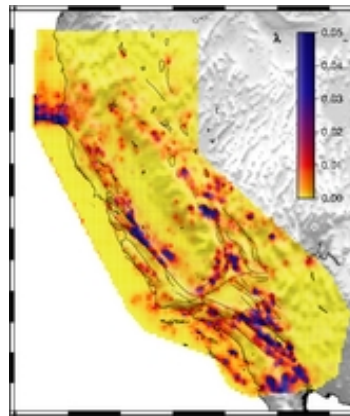
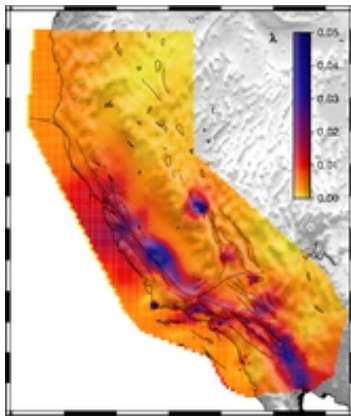
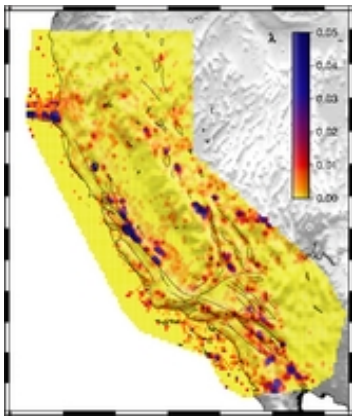
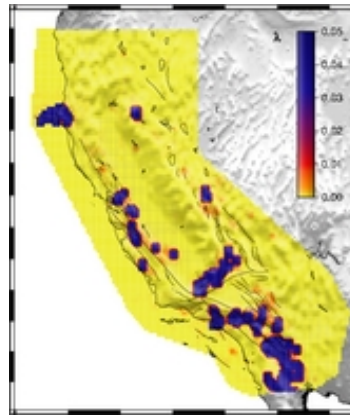
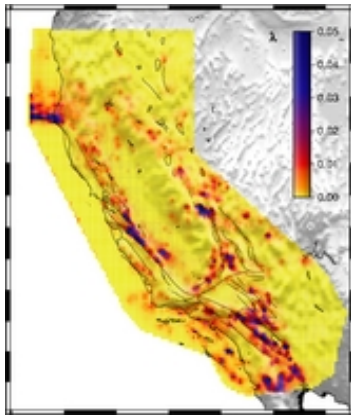
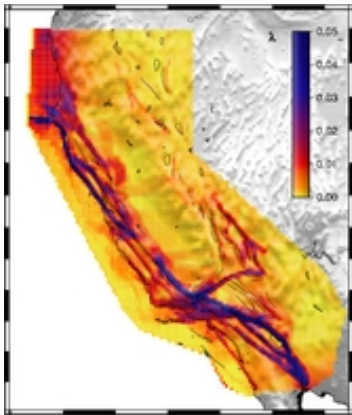


Testing Center



Testing Center (California)

19 5-year models have been submitted to the Testing Center



Bird & Liu

SHIFT main shock model
SHIFT main shock + aftershock model

Ebel et al.

5-yr main shock+aftershock model
5-yr main shock model

Helmstetter, Kagan, Jackson

HKJ 2005 long-term main shock model
HKJ 2005 long-term main shock + aftershock model

Holliday et al.

Pattern Informatics

Kagan et al.

5-yr main shock model
5-yr main shock + aftershock model

Shen, Jackson, and Kagan

Geodetic main shock model
Geodetic main shock + aftershock model

Ward

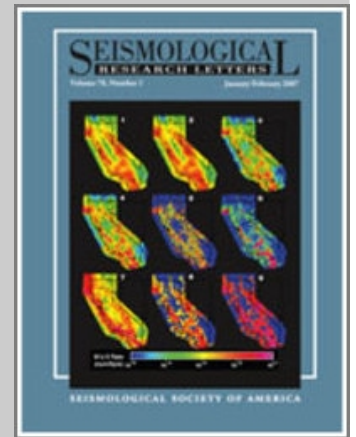
combo81
geodetic81
geodetic85
geologic81
seismic81
simulation

WG 2002

National Hazard Model

Wiemer & Schorlemmer

Asperity Likelihood Model



Community Standards

Working Groups

Data

- Working together with ANSS
- Review Process of work in Italy

Global & Model

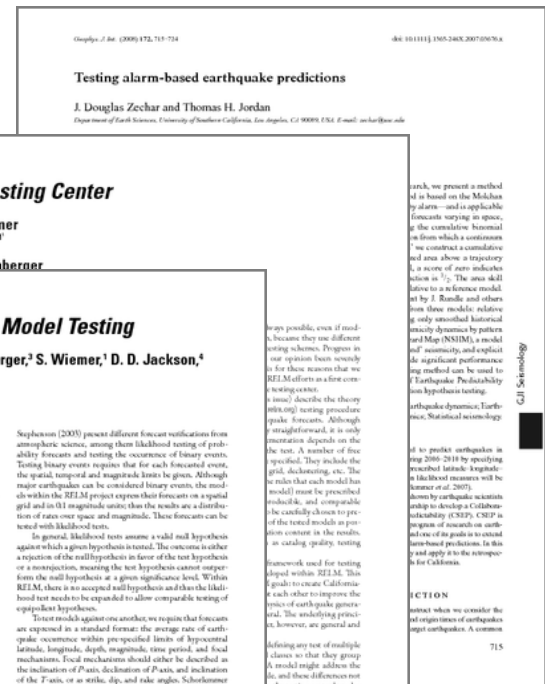
- Meeting 21 April 2008

Cyberinfrastructure

- Software review meeting on 19 November 2007 at USC

Testing

- Meeting 5 February 2008



RELIM Testing Center

D. Schorlemmer
ETH Zurich, Switzerland

M. C. Gerstenberger

Earthquake Likelihood Model Testing

D. Schorlemmer,^{1,2} M. C. Gerstenberger,³ S. Wiemer,¹ D. D. Jackson,⁴
and D. A. Rhoades⁵

INTRODUCTION

The Regional Earthquake Likelihood Models (RELIM) project aims to produce and evaluate alternate models of earthquake potential (probability per unit volume, magnitude, and time) for California. Based on differing assumptions, these models are produced to test the validity of their assumptions and to explore which models should be incorporated in seismic hazard and risk evaluation. Tests based on physical and geological criteria are useful but we focus on statistical methods using future earthquake catalog data only. We envision two evaluations: a test of consistency with observed data and a comparison of all pairs of models for relative consistency. Both tests are based on the likelihood method, and both are fully prospective (i.e., the models are not adjusted to fit the test data). To be tested, each model must assign a probability to any possible event within a specified region of space, time, and magnitude. For our tests the models must use a common format: earthquake rates in specified "bins" with location, magnitude, time, and focal mechanism limits.

Seismology cannot yet deterministically predict individual earthquakes; however, it should seek the best possible models for forecasting earthquake occurrences. This paper describes the statistical rules of an experiment to examine and test earthquake forecasts. The primary purpose of the tests described below are to evaluate physical models for earthquakes, assess that source models used in seismic hazard and risk studies are consistent with earthquake data, and provide quantitative measures by which models can be assigned weights in a consensus model or be judged as suitable for particular regions.

In this paper we develop a statistical method for testing earthquake likelihood models. A companion paper (Schorlemmer and Gerstenberger 2007, this issue) discusses the actual implementation of these tests in the framework of the RELIM initiative.

Statistical testing of hypotheses is a common task and a wide range of possible testing procedures exist. Jelleff and

Stephenson (2000) present different forecast verifications from atmospheric sciences, among them likelihood testing of probability forecasts and testing the occurrence of binary events. Testing binary events requires that for each forecasted event, the spatial, temporal and magnitude limits be given. Although major earthquakes can be considered binary events, the models within the RELIM project express their forecasts on spatial grid and in 0.1 magnitude units; thus the results are a distribution of rates over space and magnitude. These forecasts can be tested with likelihood tests.

In general, likelihood tests assume a valid null hypothesis against which a given hypothesis is tested. The outcome is either a rejection of the null hypothesis in favor of the test hypothesis or a nonrejection, meaning the test hypothesis cannot outperform the null hypothesis at a given significance level. Within RELIM, there is an accepted null hypothesis and thus the likelihood test needs to be expanded to allow comparable testing of earthquake hypotheses.

Test models against one another, we require that forecasts are expressed in a standard format: the average rate of earthquake occurrence within pre-specified limits of hypocentral latitude, longitude, depth, magnitude, time period, and focal mechanisms. Focal mechanisms should either be described as the inclination of P -axis, declination of P -axis, and inclination of the T -axis, or as strike, dip, and rake angle. Schorlemmer and Gerstenberger (2007, this issue) designed classes of these parameters such that similar models will be tested against each other. These classes make the forecasts comparable between models. Additionally, we are limited to testing only what is precisely defined and consistently reported in earthquake catalogs. Therefore it is currently not possible to test such information as fault rupture length or area, epicenter location, etc. Also, to account for data quality issues, we allow for location and magnitude uncertainties as well as the probability that an event is dependent on another event.

As we mentioned above, only models with comparable forecasts can be tested against each other. Our current tests are designed to examine grid-based models. This requires that any fault-based model be adapted to a grid before testing is possible. While this is a limitation of the testing, it is an inherent difficulty in any such comparative testing. Please refer to appendix B for a statistical evaluation of the application of the Poisson hypothesis to fault-based models.

The testing suite we present consists of three different tests: L-Test, N-Test, and R-Test. These tests are defined similarly to

ways possible, even if models, because they use different testing schemes. Progress in our opinion been severely for these reasons that we RELIM efforts in a five-year testing center.

Figure 1 shows the theory (http://www.relcenter.org) testing procedure for forecasts. Although straightforward, it is only implementation depends on the the test. A number of free specified. They include the grid, declustering, etc. The rules that each model has model) must be prescribed beforehand, and comparable the carefully chosen to pre- of the tested models as position center in the results, as catalog, quality, testing framework used for testing shaped within RELIM. This goal is to create California each other to improve, the success of earthquake general. The underlying principles, however, are general and

defining any test of multiple classes so that they group. A model might address the fit, and these differences not in the testing center but also if are likely to be influenced processes. Comparisons of not possible. A model forecast against a model that fully model has the advantage errors, but it has low value.

rank, we present a method if is based on the Median by alarm—and is applicable forecasts varying in space, in the cumulative historical from which a continuous we construct a cumulative and area above a trajectory χ , a score of zero indicates below χ . The area still below is a forecast model, set by J. Bunde and others from three models relative to only smoothed historical seismicity dynamics by pattern and Map (NSIM), a model and" automatically, and explicit the significant performance ing method can be used to Earthquake Predictability test hypothesis testing. earthquake dynamics; Earth- science, Statistical seismicity

if to predict earthquakes in step 2005-2010 by specifying described herein. Longitude is likelihood measures will be (Jennett et al. 2007). from by earthquake scientists (group to develop a California-ability (CEEP). CEEP is program of research on scientific one of its goals is to extend time-based predictions. In this y and apply it to the response for California.

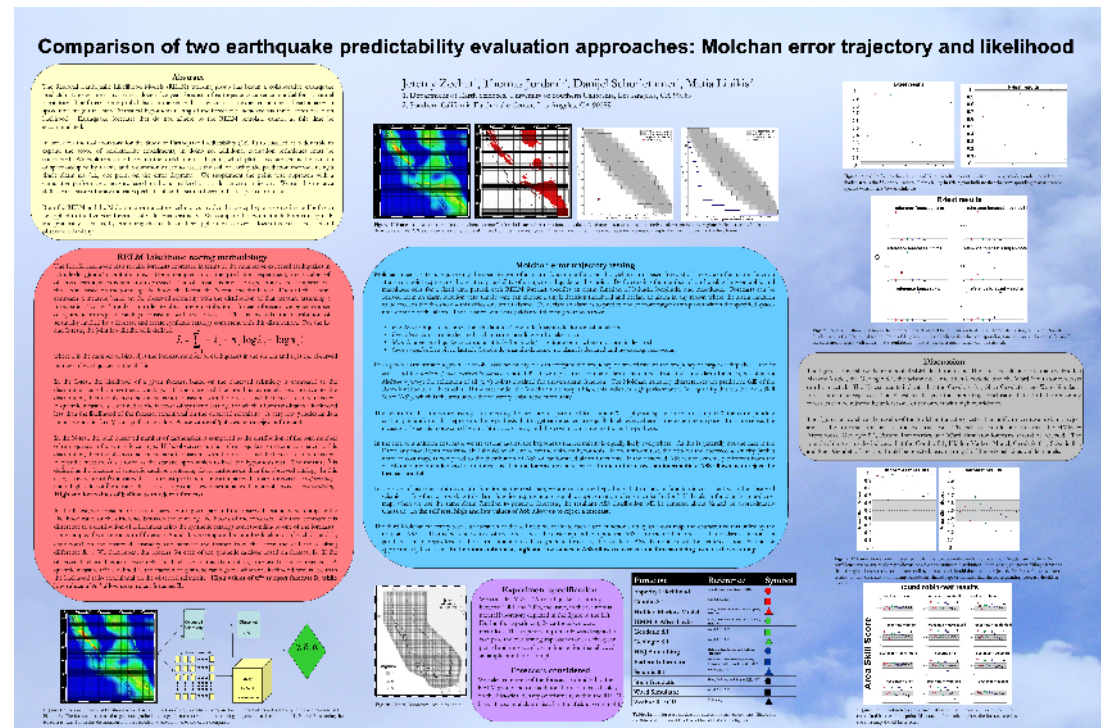
LECTION
lowest when we consider the not origin times of earthquakes major earthquakes. A common

Grid-based Testing

- Standard testing schema as developed for RELM
- Reduced large storage demands of current likelihood tests (RELM Tests)
- Rhoades & Schorlemmer are working on optimized version of likelihood tests
 - Reduce number of computation steps
 - Partly implemented in version 8.4
- Jackson, Kagan, & Schorlemmer are working on modified likelihood tests
 - Include different probability distributions
 - Allows for including uncertainties in forecast generation

Alarm-based Testing

- Different methods exist (Molchan, ROC, etc.)
- Zechar is working to introduce the ASS (Area Skill Score) to version 8.10
- Comparison of results with likelihood testing

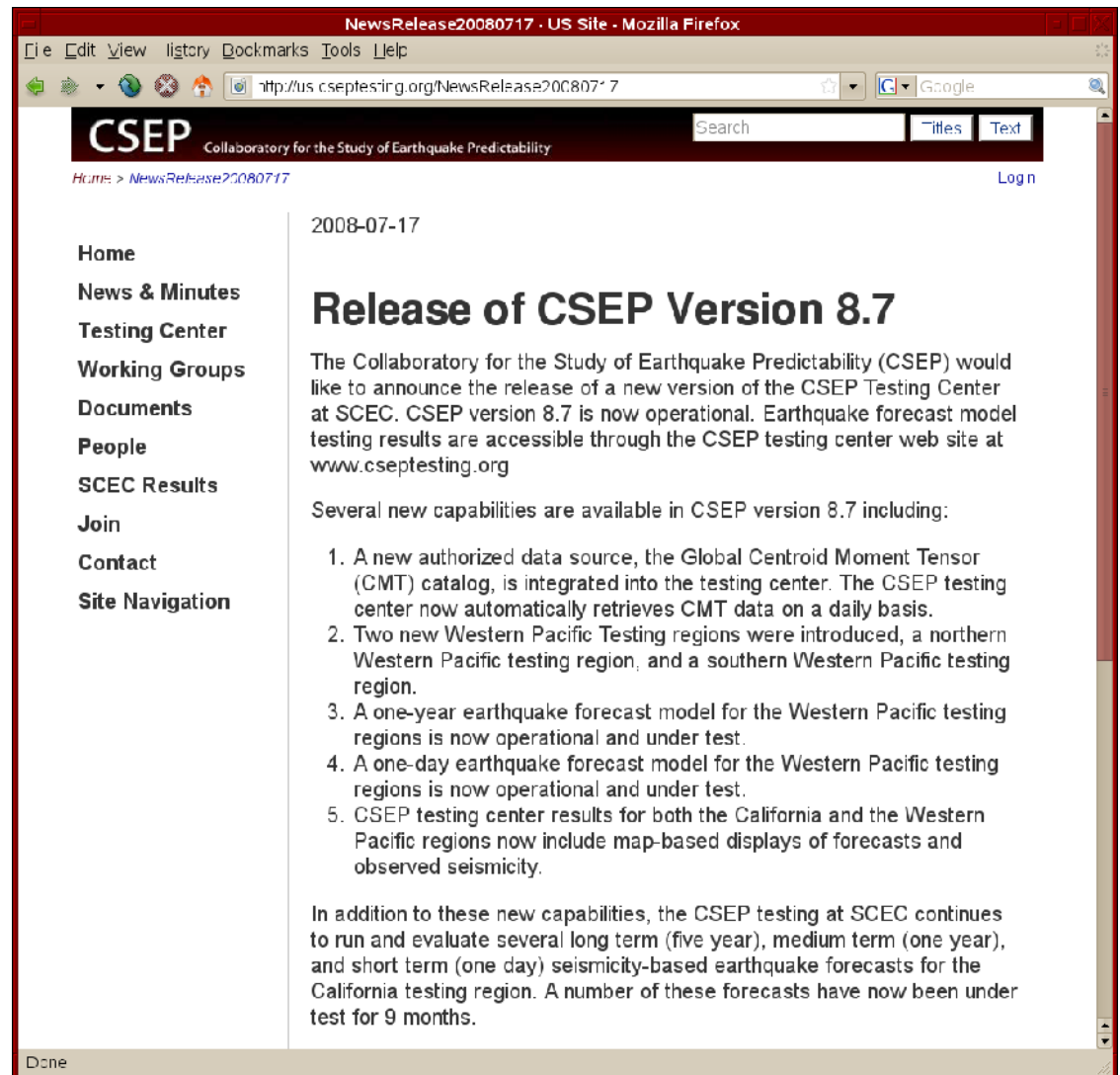


Fault-based Testing

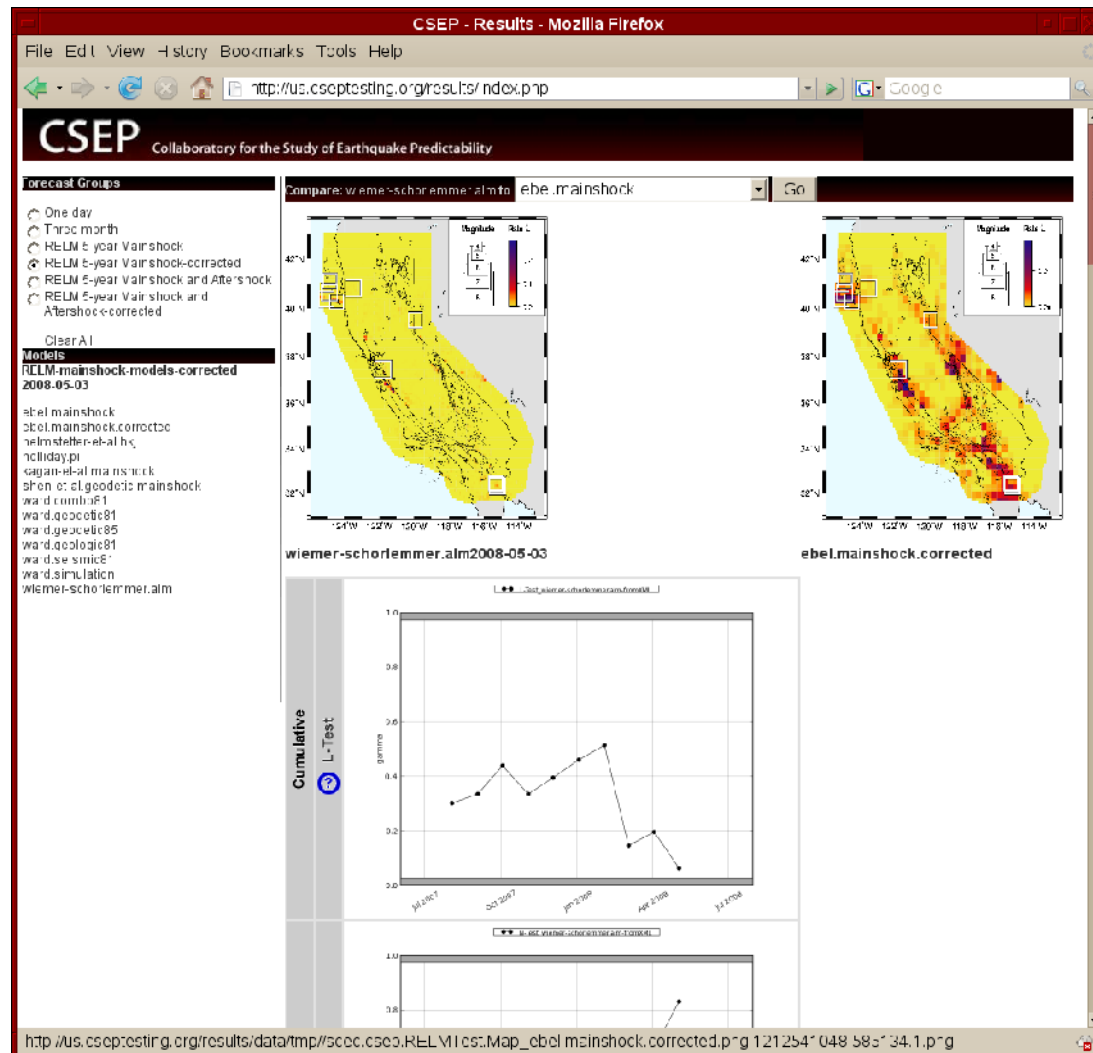
- Meeting held in April 2007 at USC
- No appropriate authorized data source identified
 - How to determine the ruptured fault?
 - How to determine the affected fault segments?
 - What about earthquake off known faults?
- Grid-based testing with focal mechanism information
 - SCEC community fault model
- Jackson, Kagan, and Schorlemmer are assessing possible earthquake data sources
- No implementation plans yet

Communication Protocols

- News Releases
- Mailing lists
- Weekly minutes posted on website



Communication Protocols



- Result webpages
- CSEP reports to CEPEC & NEPEC

CSEP Web-Presentation Concept

3 Websites

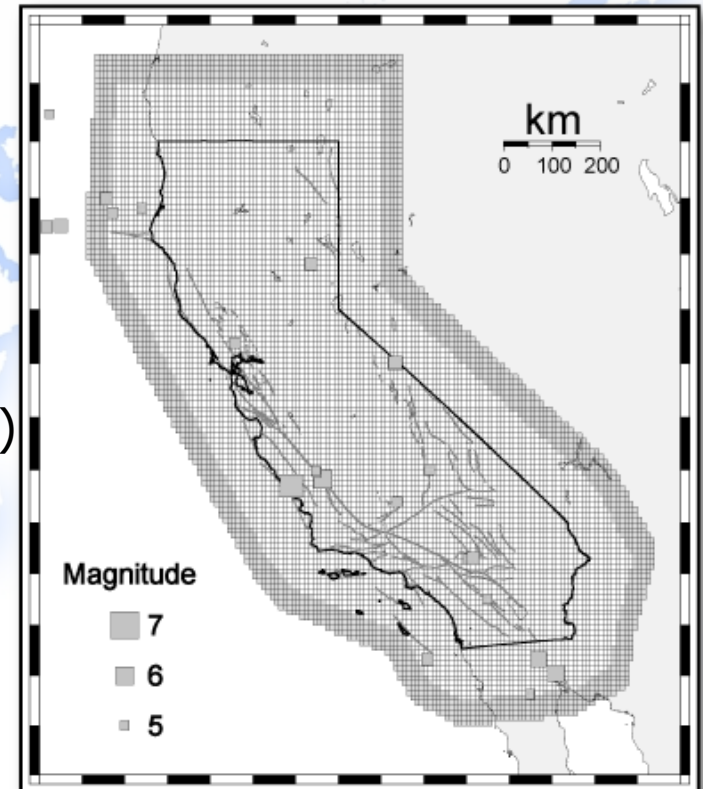
- Main CSEP website www.cseptesting.org (static)
- Regional websites (editable)
 - us.cseptesting.org
 - nz.cseptesting.org
 - eu.cseptesting.org
 - jp.cseptesting.org
- Result pages us.cseptesting.org/SecResults (restricted)
 - Other centers can use this facility for their results

Testing Regions

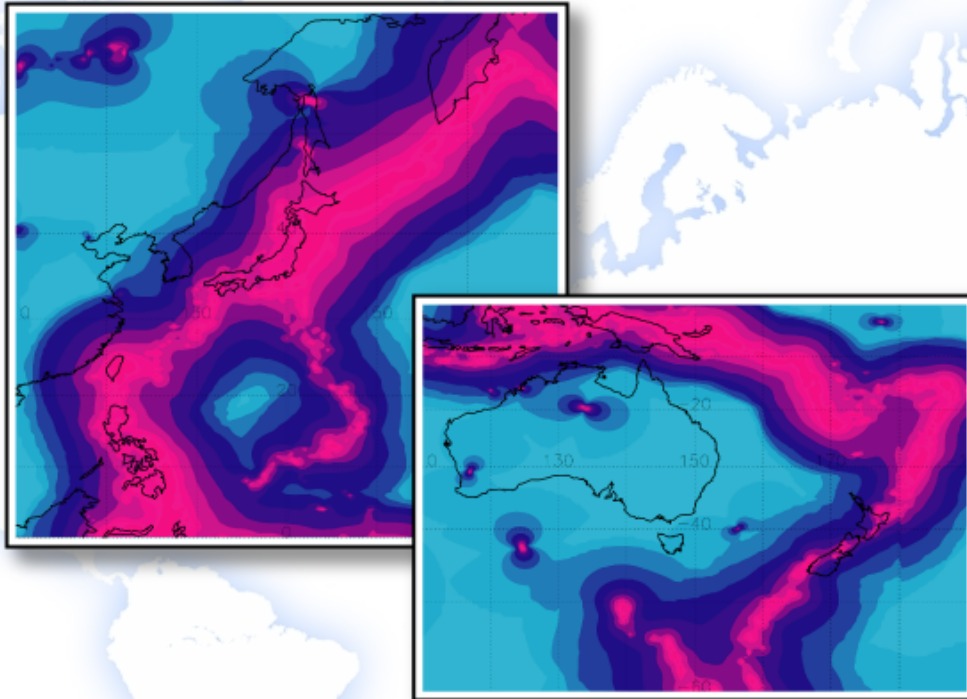
- Delineated region with defined areas for data collection and prediction testing
- Sponsorship by a regional organization of earthquake scientists willing to participate in CSEP
- Data streams authorized by agreements with appropriate regional agencies, including a low-latency earthquake catalog for testing prospective predictions
- Calibration of the seismic networks, including the quantification of hypocenter & magnitude uncertainties and mapping of completeness thresholds

California

- Operational since 1.9.2007
- Current models
 - 5-year RELM
 - 1-day STEP & ETAS
 - 3-month EEPAS & PPE
- Upcoming models
 - ETAS (Werner)
 - Cellular Seismology (Kafka)
 - STEP Java (Gerstenberger)



Western Pacific



- Covers >50% of worldwide seismicity
- Testbed for global testing
- Testbed for Global CMT catalog
- Implementation in 2008 (8.7)

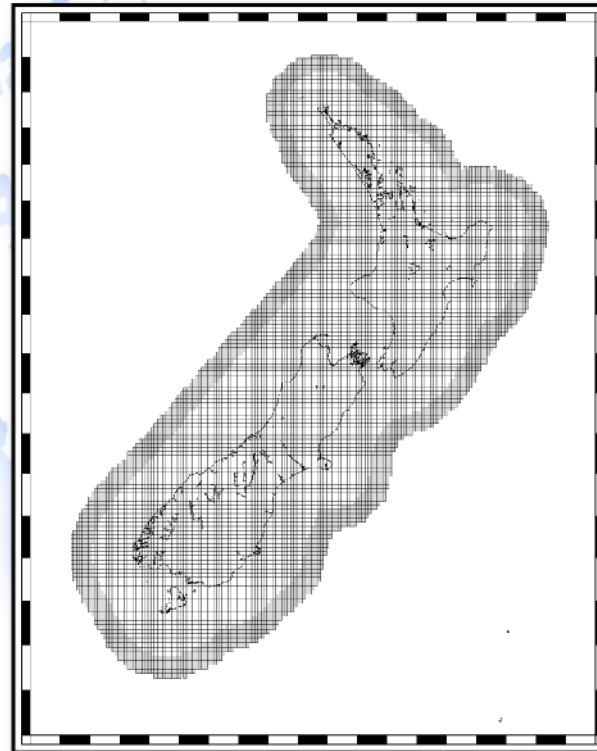
Basin & Range



- Meeting held in April at USC
- Area covered by 7 networks
- ANSS does not provide sufficient data quality
- No models available
- Not likely to happen

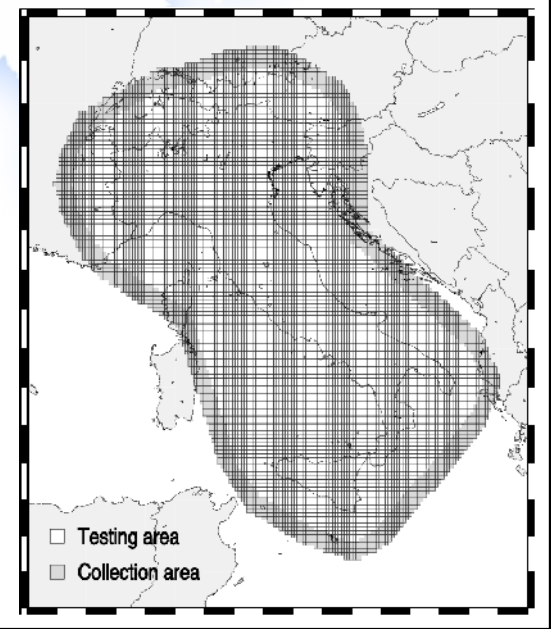
New Zealand

- Testing area defined
- Catalog including location parameter uncertainties
- Assumed overall completeness at $M=4$
- Declustering (same method as used in national hazard assessment)
- RELM Tests (N-, L-, and R-Test)
- New tests under development
- Models
 - 4 5-year models
 - 4 3-month models
 - 4 1-day models



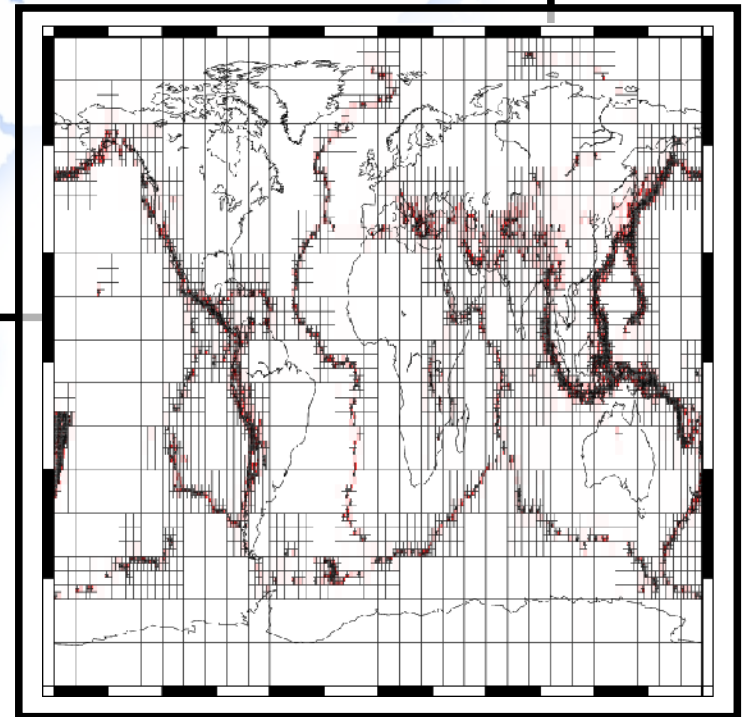
Europe

- ETH Testing Center operational
- Implementation of testing region Italy underway
- Next possible regions (to be tested at ETH)
 - Greece
 - Iceland
 - Turkey
- Use the SCEC facilities for web presentations



Global

- First steps taken
- 3 testing area definitions
 - uniform grid
 - uniform grid covering only seismically active areas
 - non-uniform grid (importance grid)
- Models
 - Expand Western Pacific models for global testing
 - EEPAS/PPE models
 - Smoothed seismicity
 - GALM
- Global CMT catalog
- Global completeness study



Japan

- Getting started in Japan
 - Testing center installation (Euchner)
 - Model installation (Nanjo)
 - Data characterization:
Completeness study for Japan (Schorlemmer)

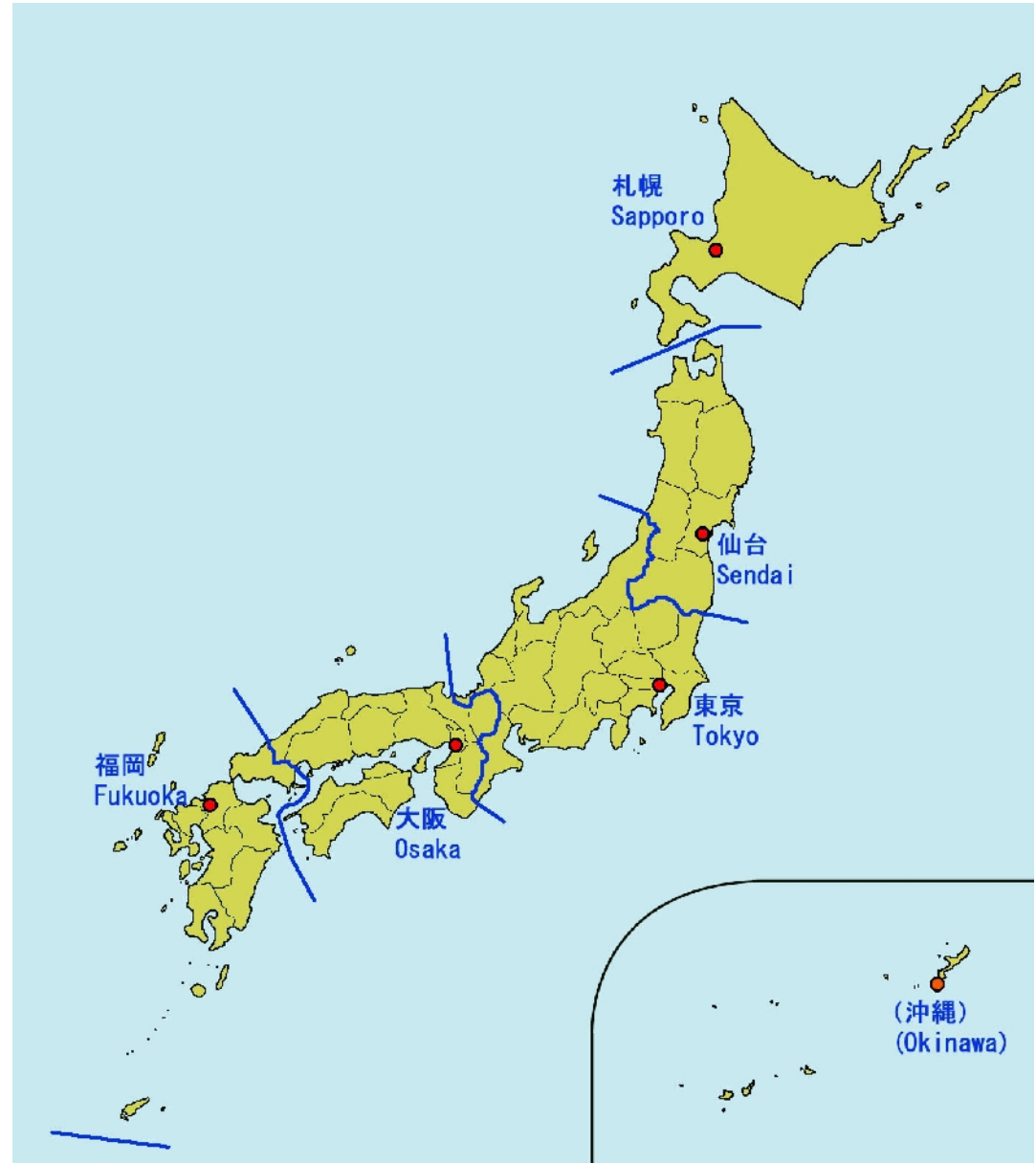
Japan

JMA (+HiNet)

- ~1000 stations
- 6 districts
- overall high data quality

Important for CSEP:

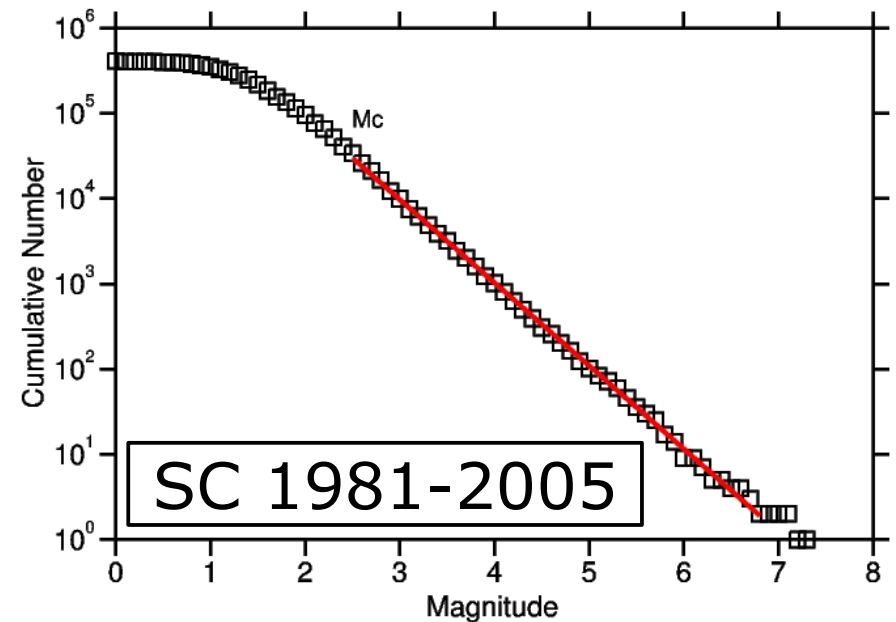
- completeness of deep seismicity
- offshore completeness
- homogeneity of reporting



What is Completeness?

Completeness is usually defined as the magnitude of completeness, M_c :

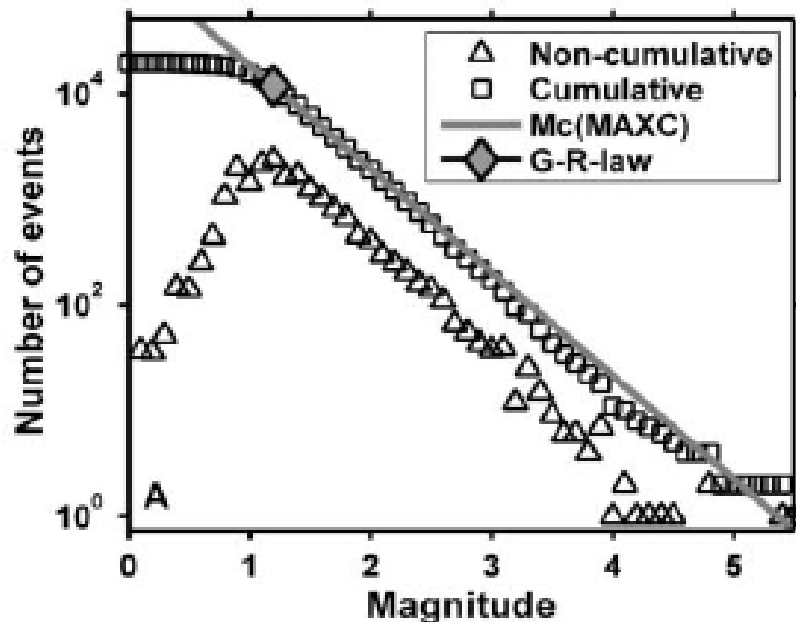
- M_c describes the magnitude of the smallest events completely detected by the network.
- M_c itself is defined as the deviation point from the “Gutenberg-Richter”-line in a frequency-magnitude distribution of an earthquake sample.



Traditional Methods

Maximum Curvature

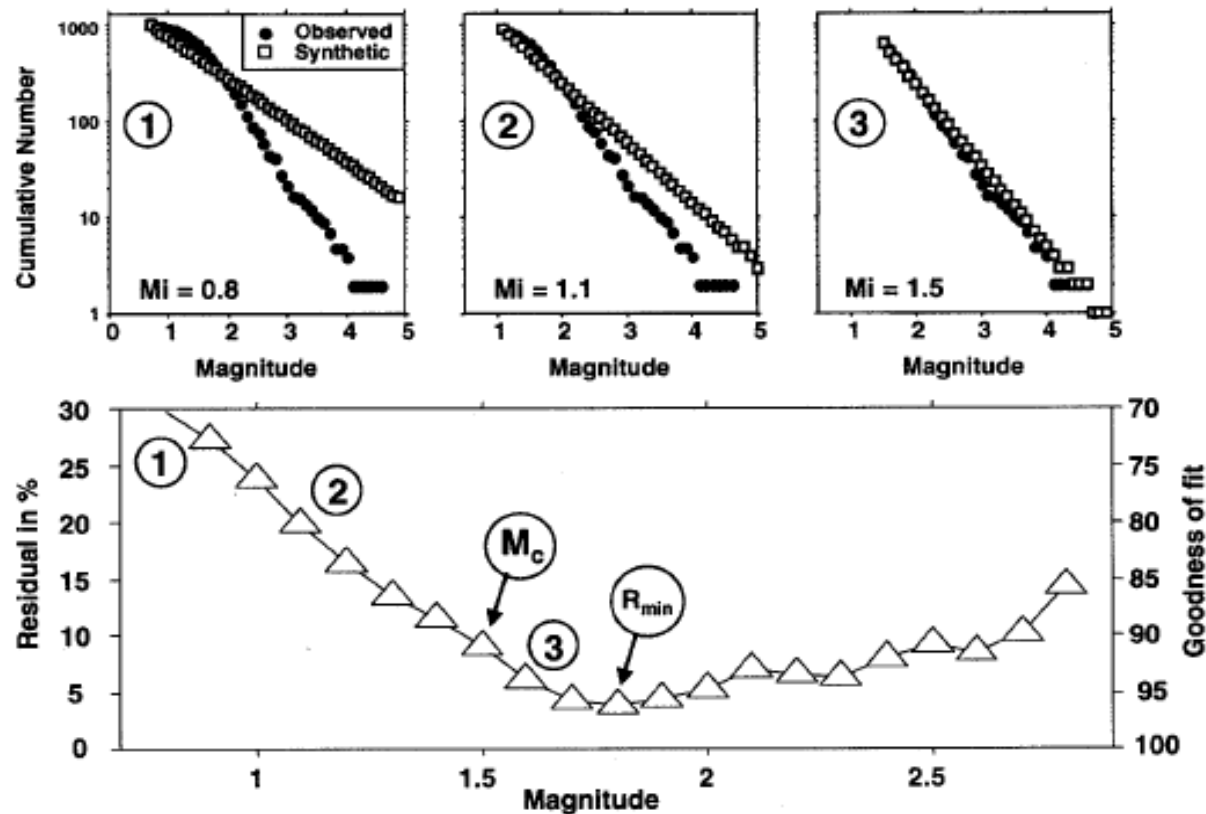
- Defines M_c as the magnitude value with the highest curvature in the frequency-magnitude distribution.
- The non-cumulative magnitude bin with the highest number of events
- SCSN catalog with 0.01 binning needs to be rebinned to 0.1



Traditional Methods

Goodness of Fit

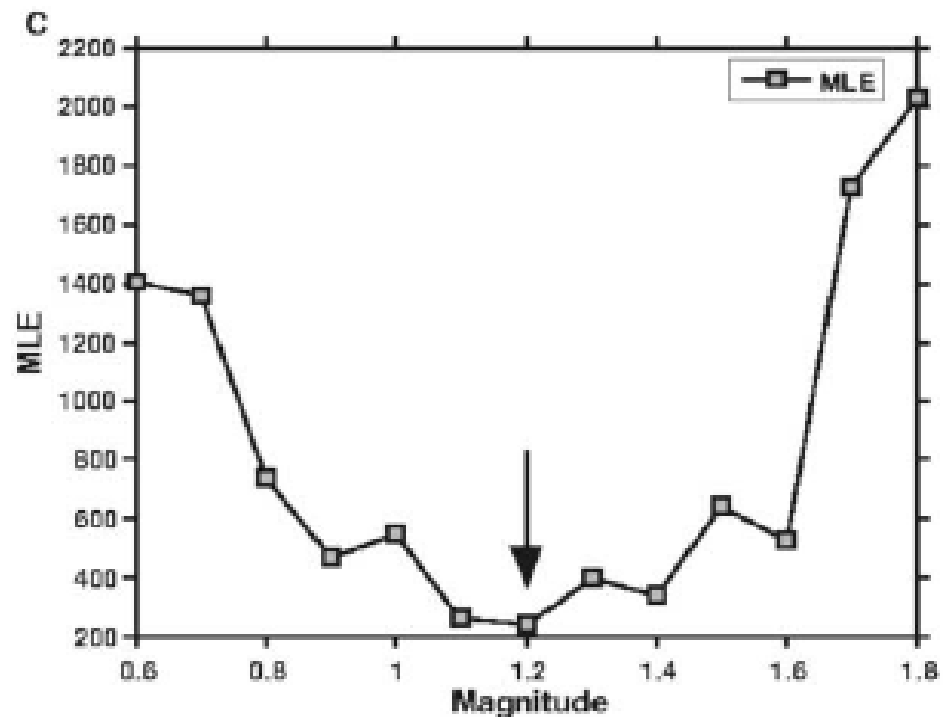
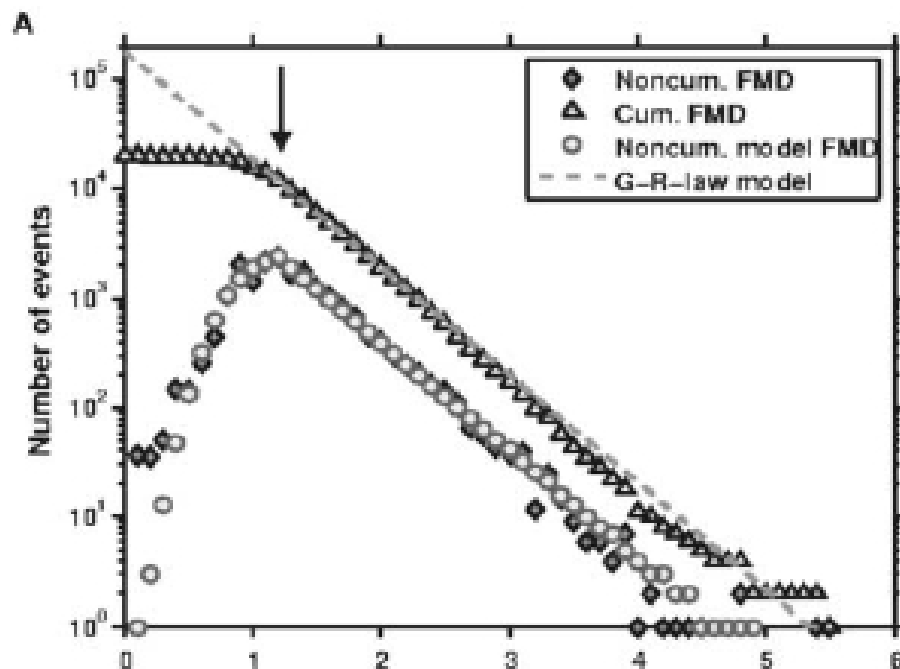
- Searches through the magnitude space and measures the goodness of fit of the b-value line.
- Does often not reach the desired 90% level.



Traditional Methods

Entire Magnitude Range (EMR)

- Searches also through the magnitude space but assumes power-law and log-normal distributions.
- Method with the largest number of assumptions.



Traditional Methods

Assumptions:

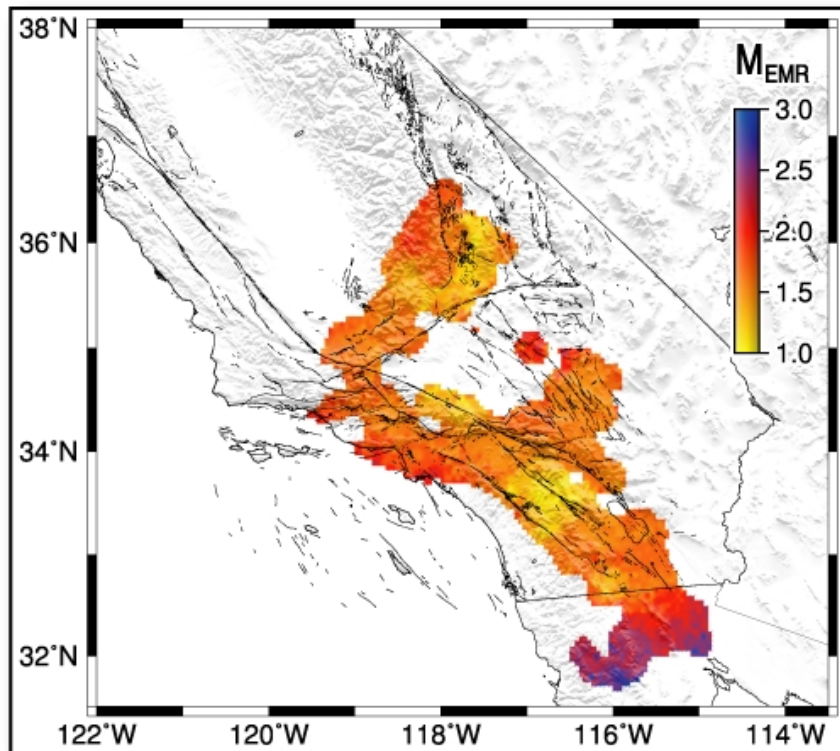
- Earthquake samples exhibit a GR-distribution
- M_c can be averaged over space (Earthquakes are sampled in circles with radii of several km)
- M_c can be averaged over time (Networks may change during the period of sampling)

Implications:

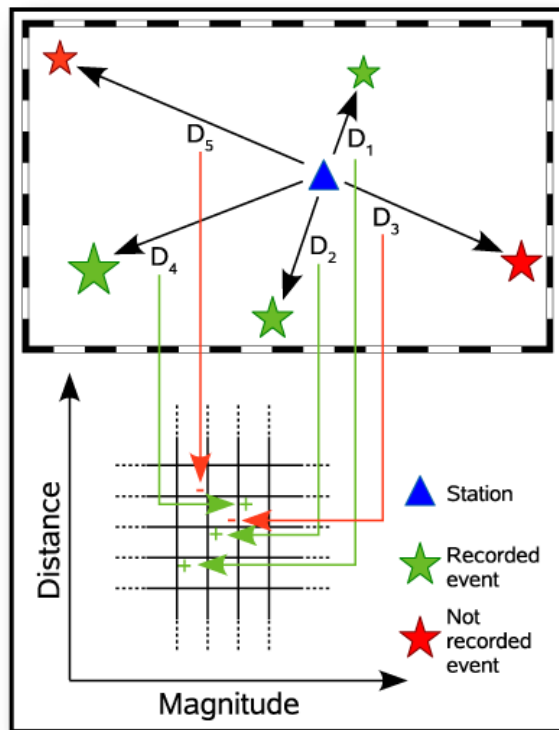
- M_c cannot be determined in low-seismicity areas
- M_c is a function of earthquake samples

New Method

The “Gutenberg-Richter”-definition is a proxy.



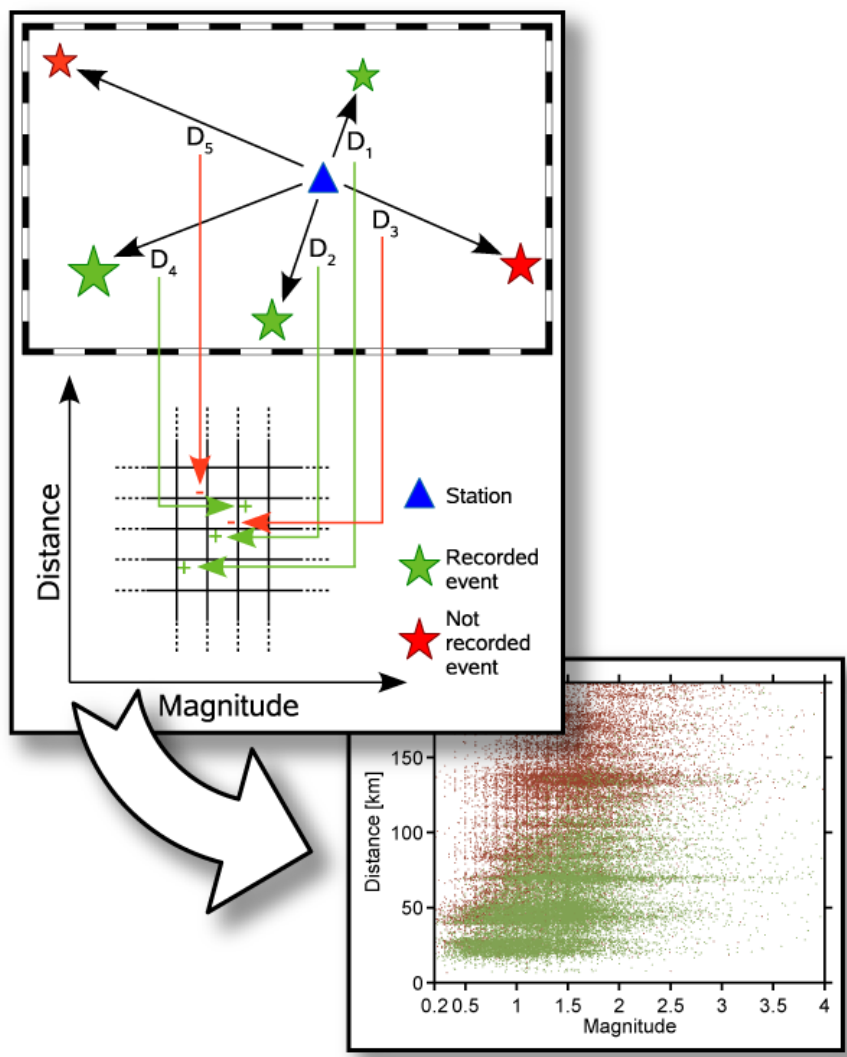
New Method



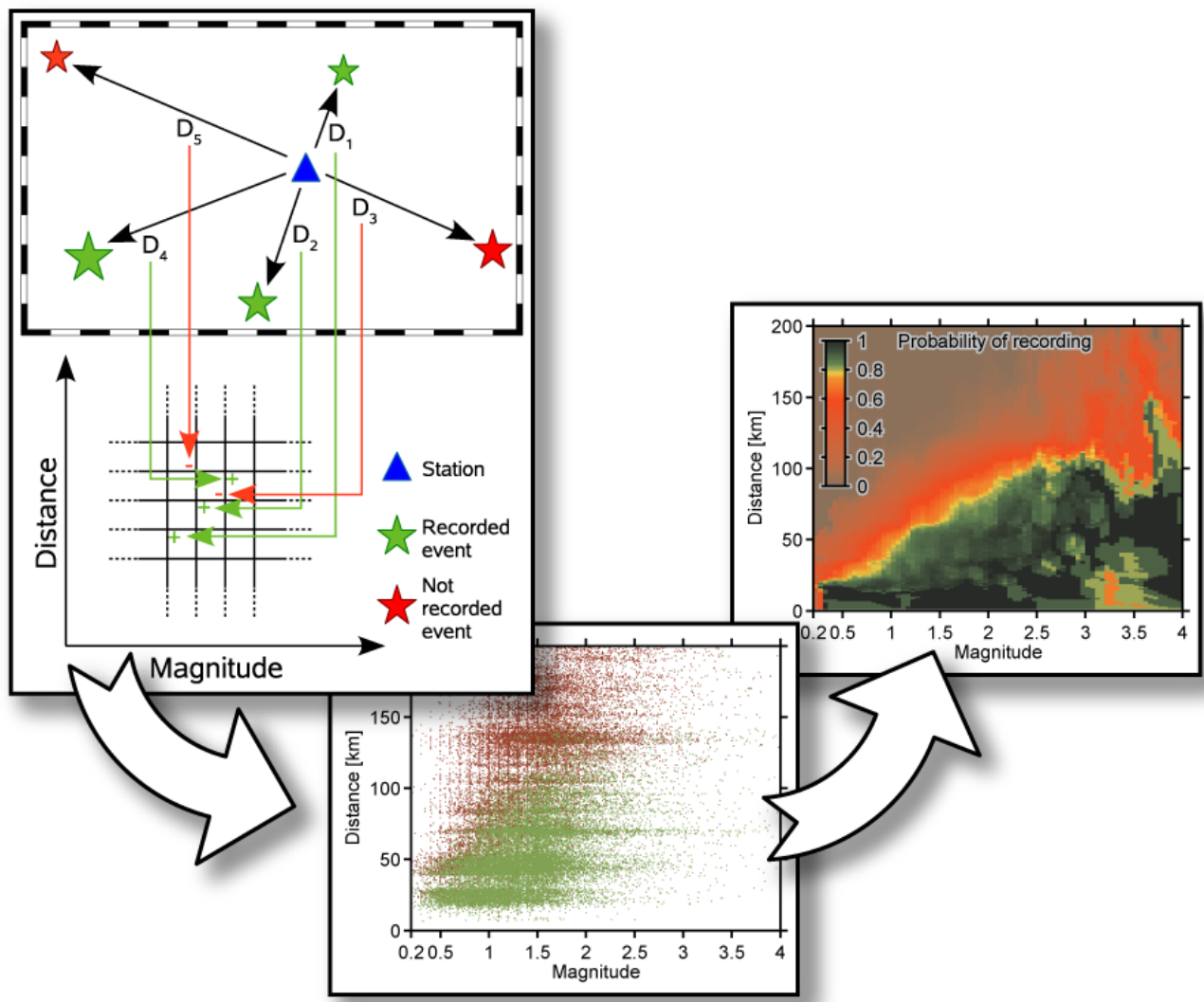
The "Gutenberg-Richter"-definition is a proxy.

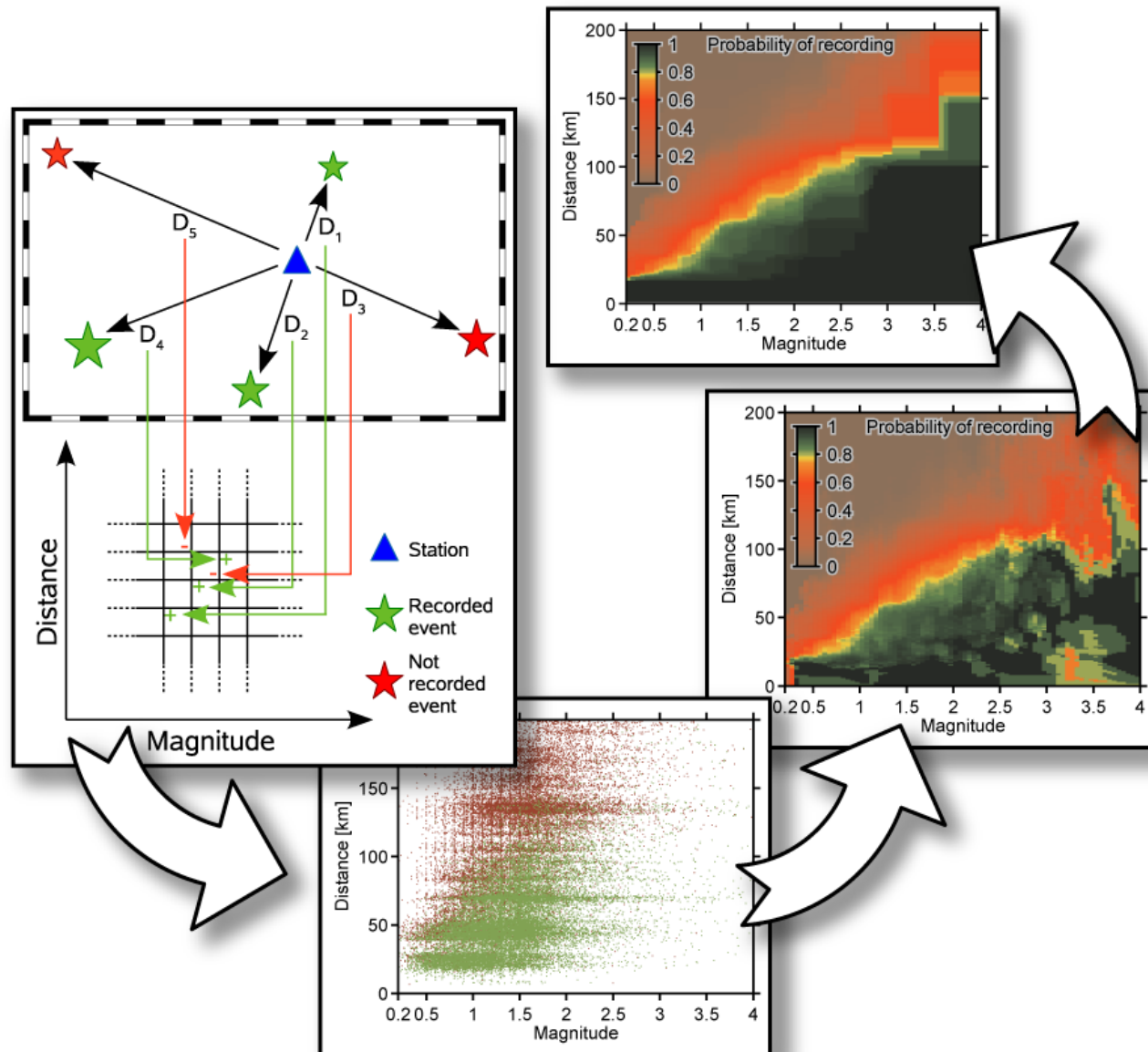
Completeness should be described by the station capabilities of detecting events of certain magnitudes

New Method

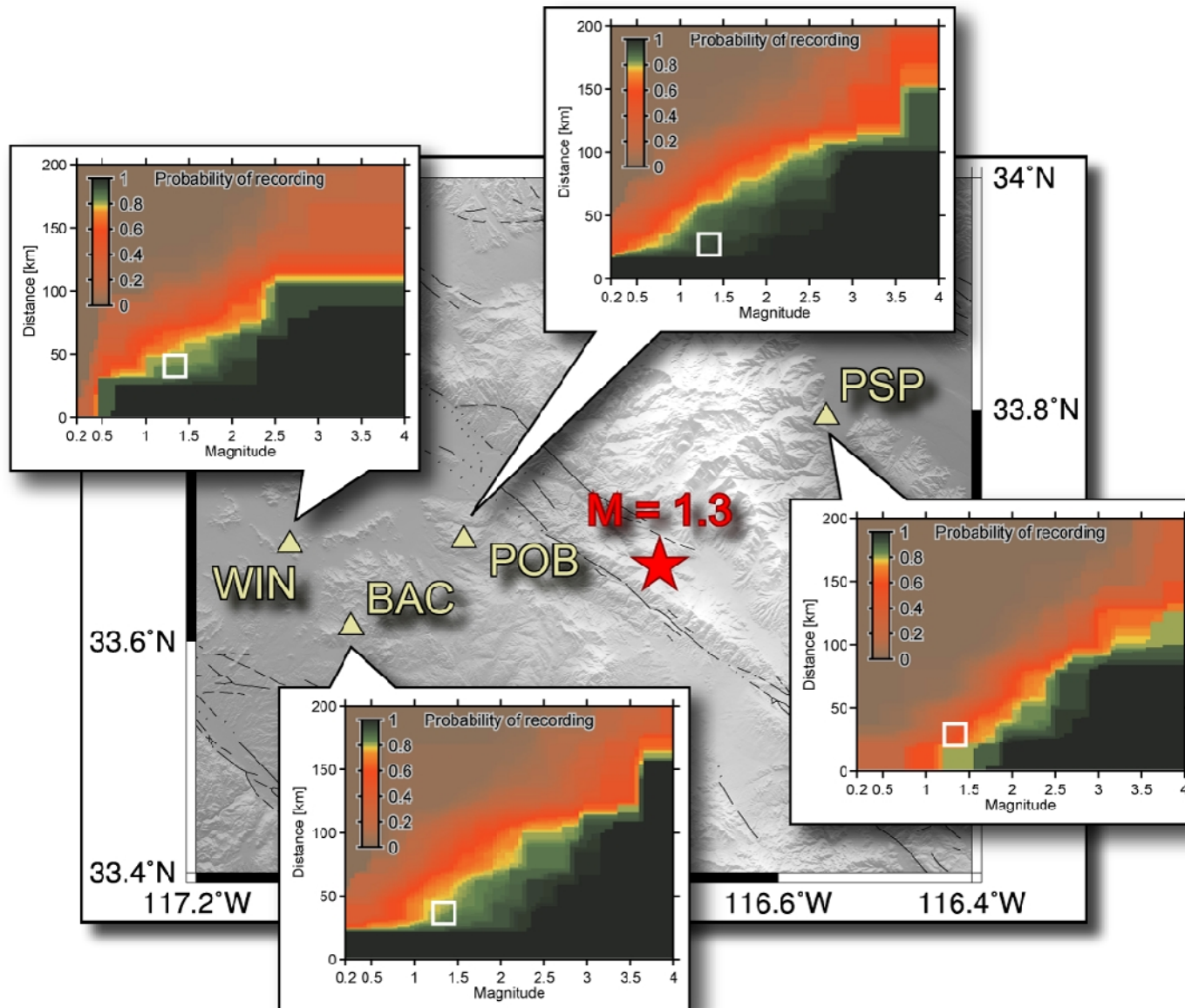


New Method

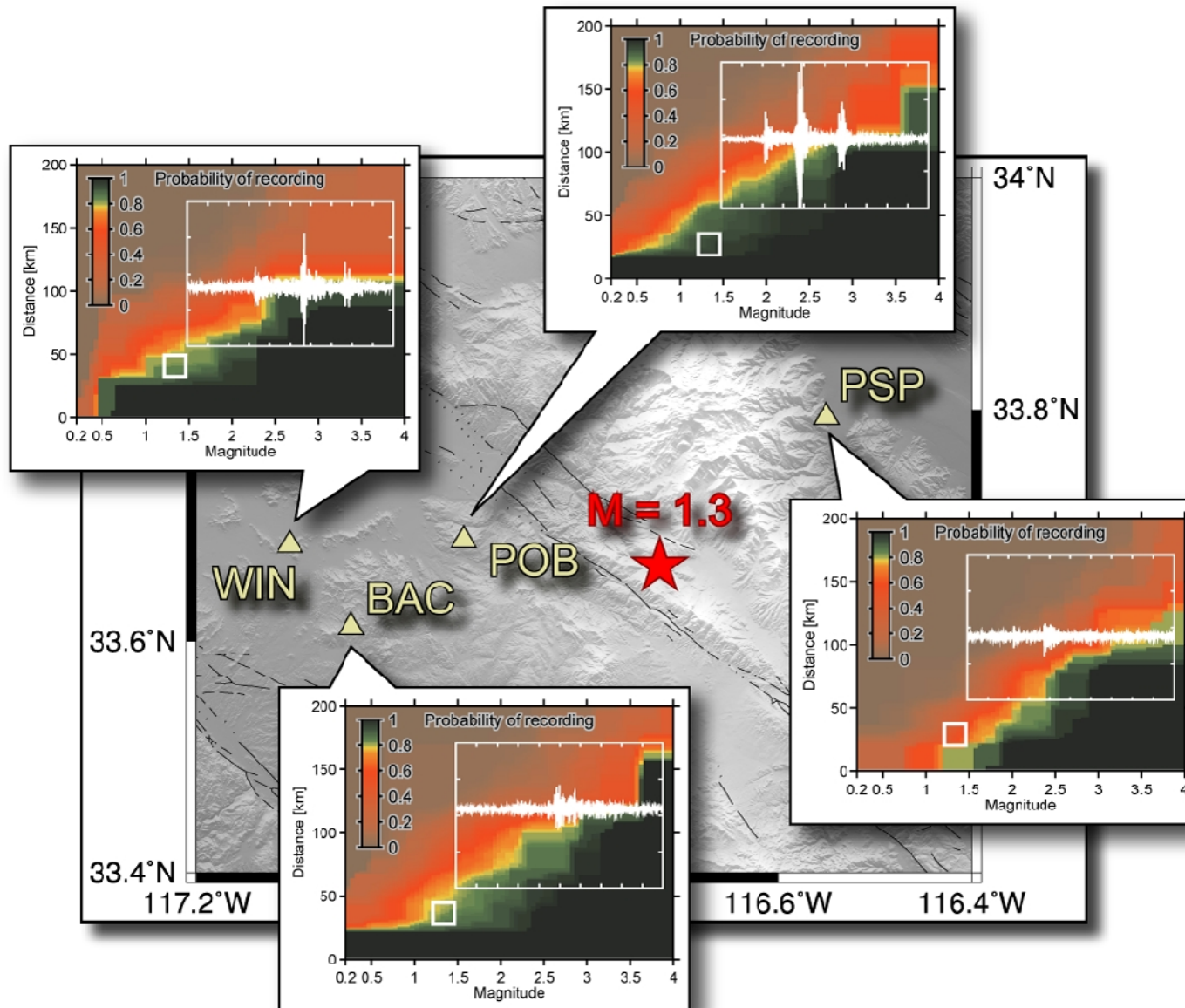




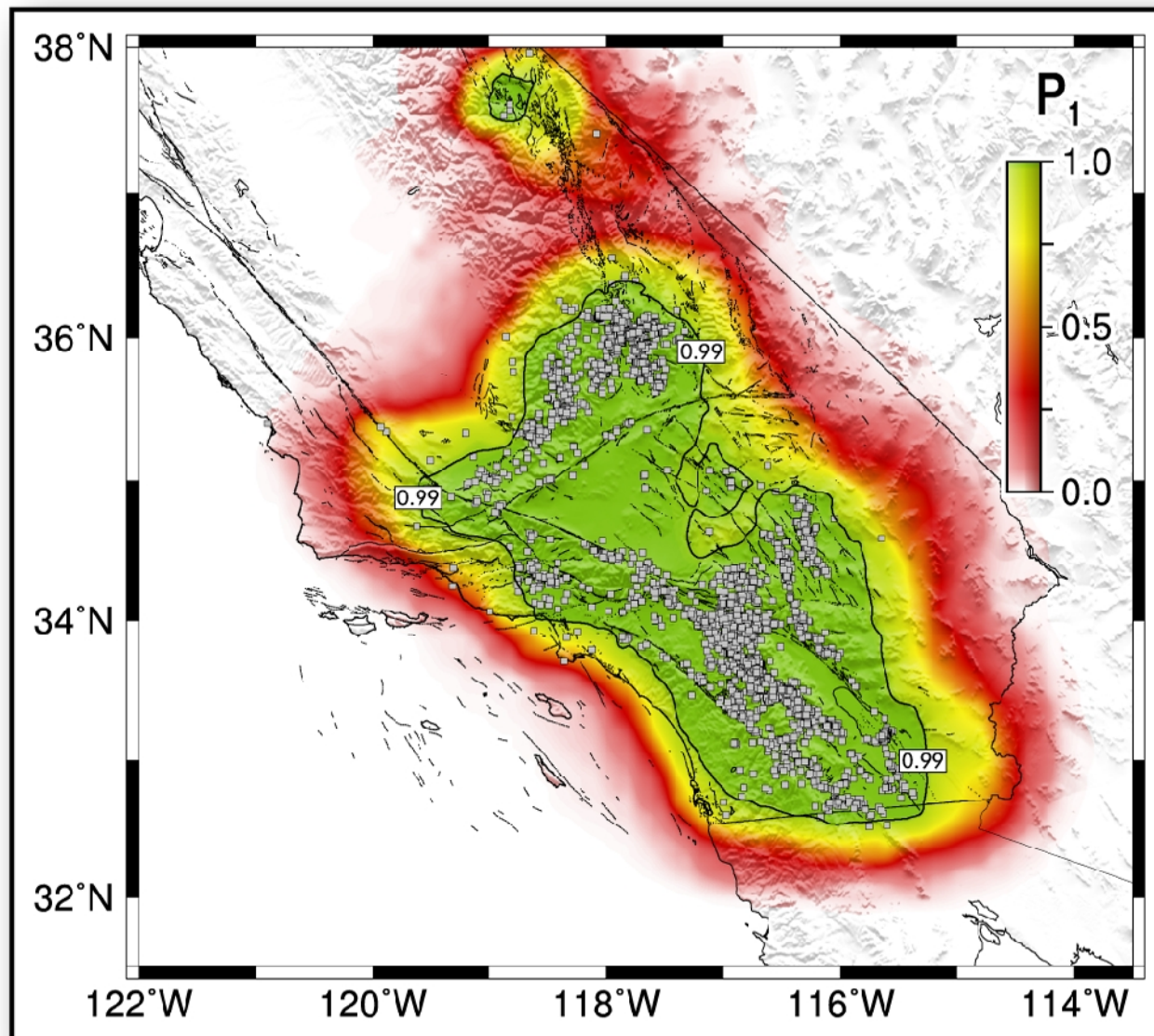
Station Recording Capabilities



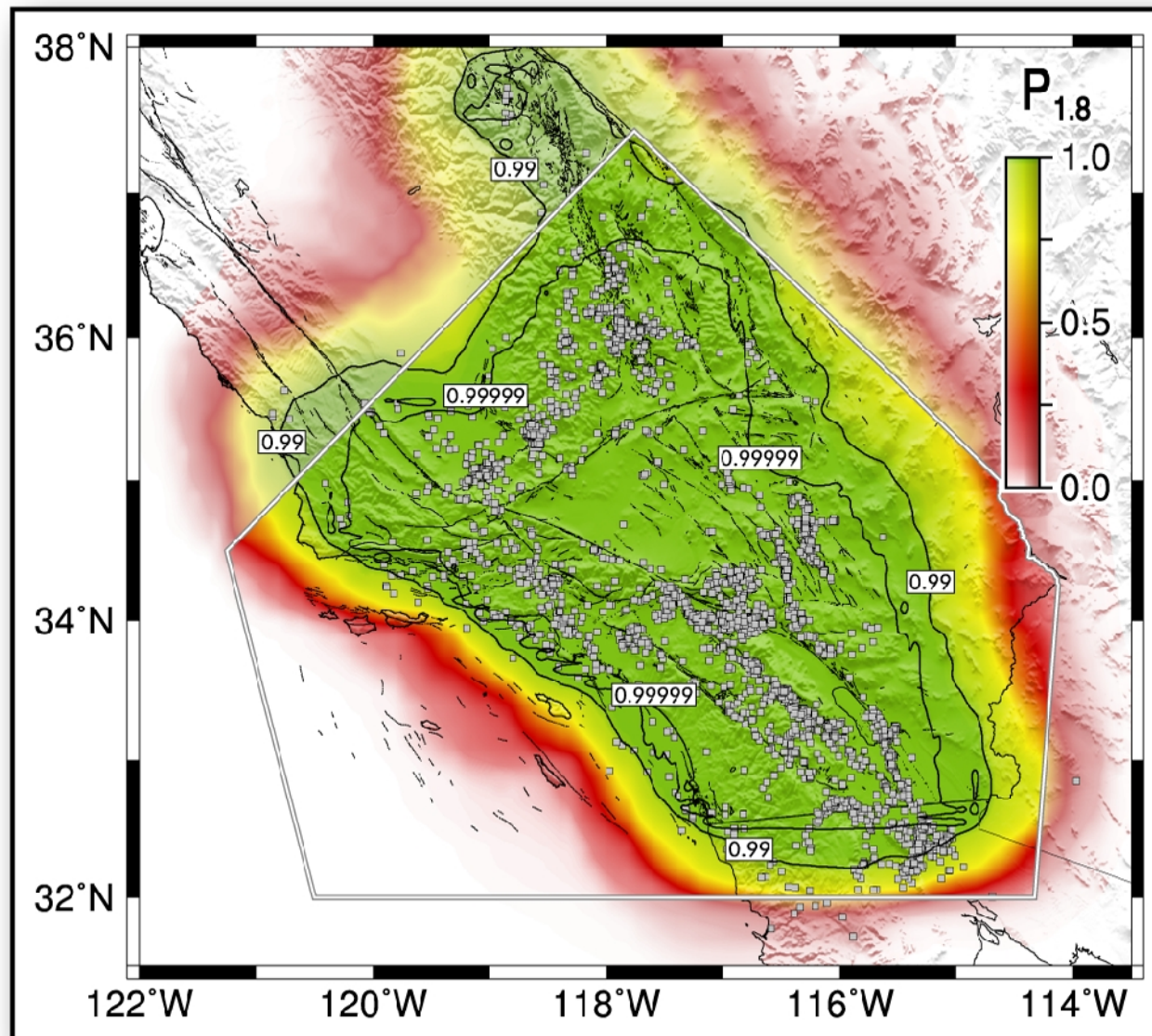
Station Recording Capabilities



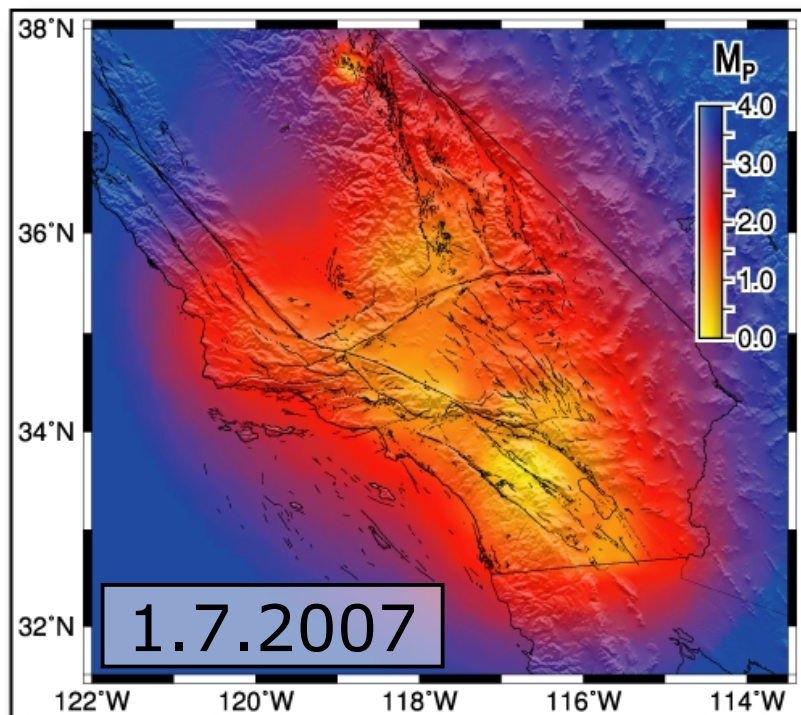
Probability of Detecting Events



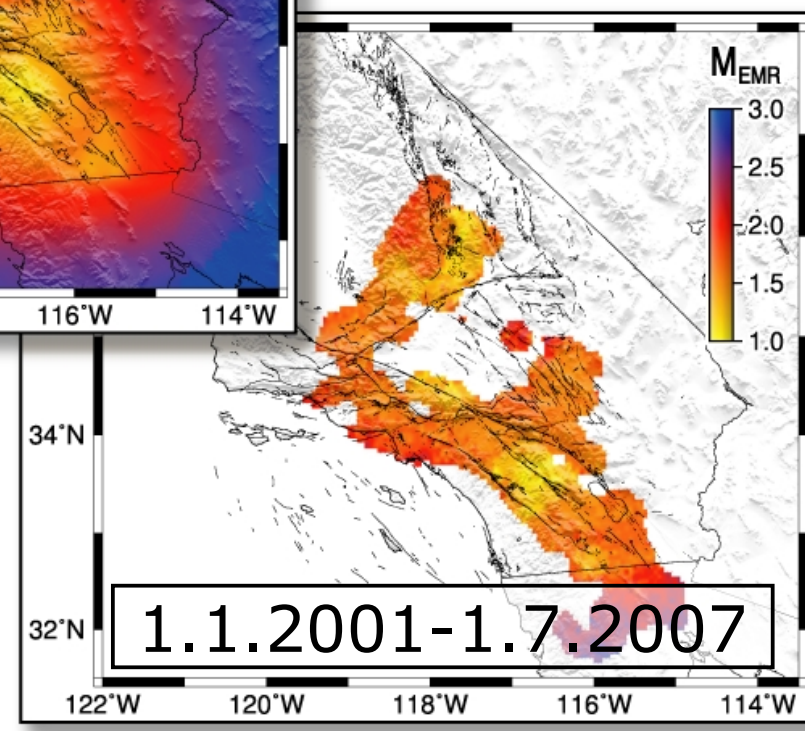
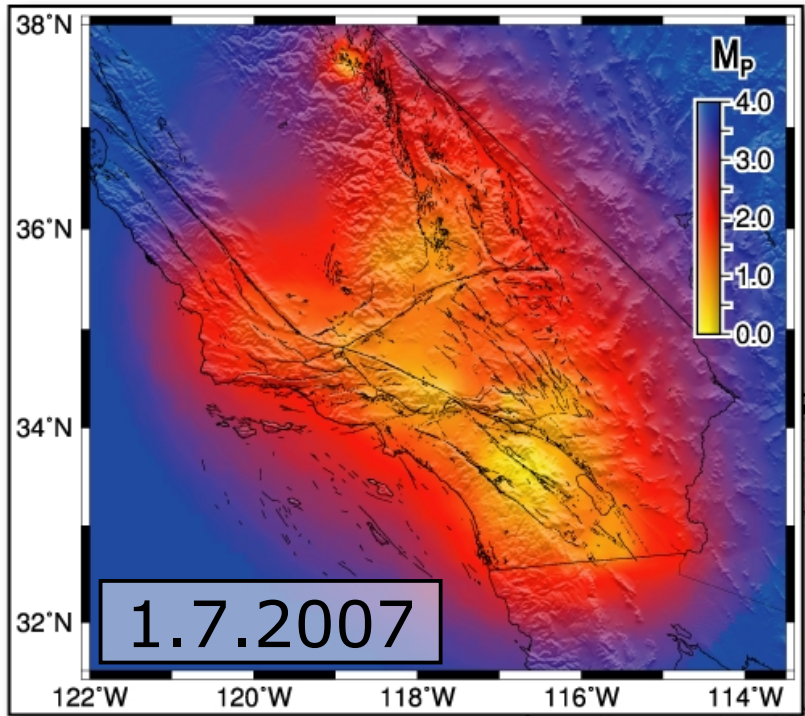
Probability of Detecting Events



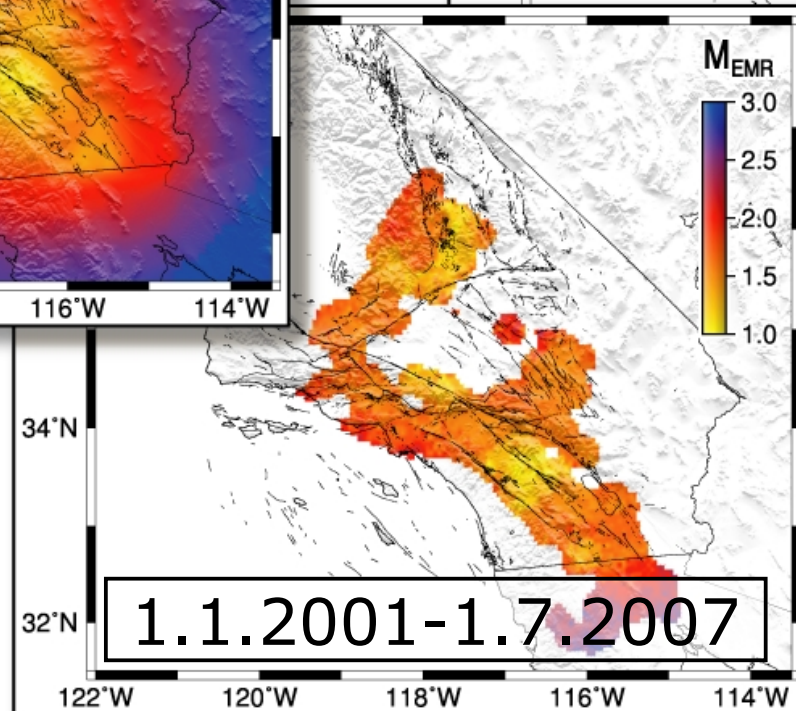
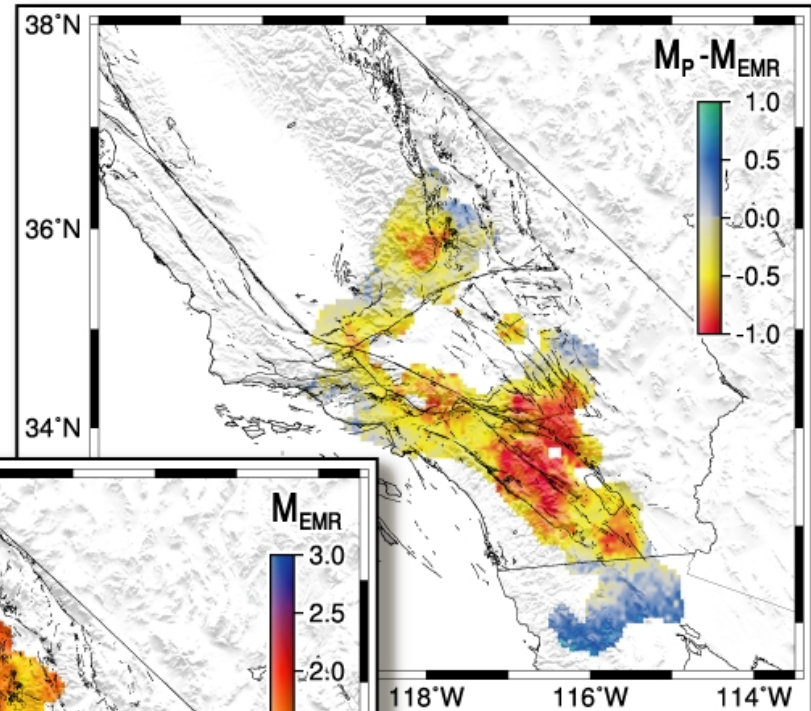
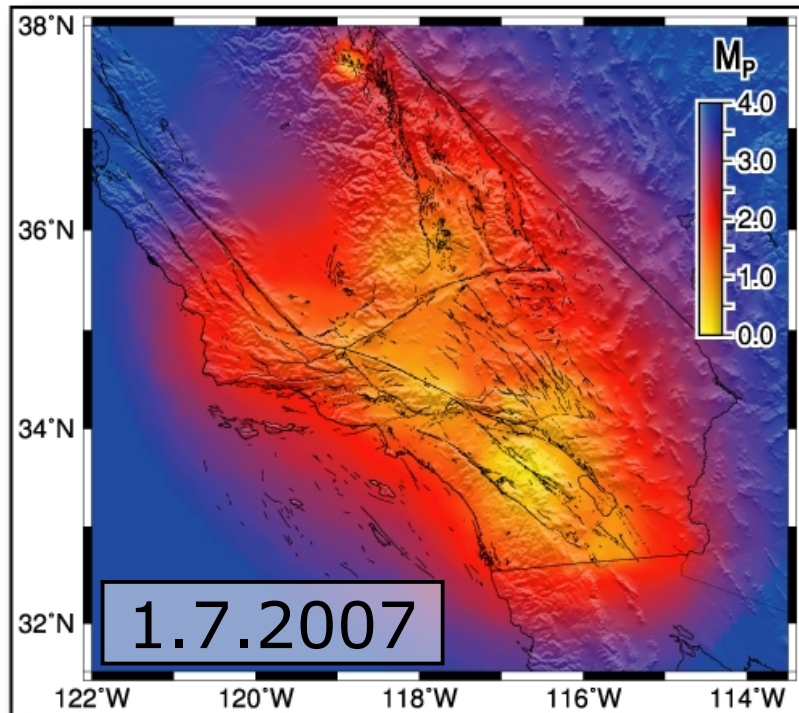
Magnitude of Completeness



Magnitude of Completeness



Magnitude of Completeness

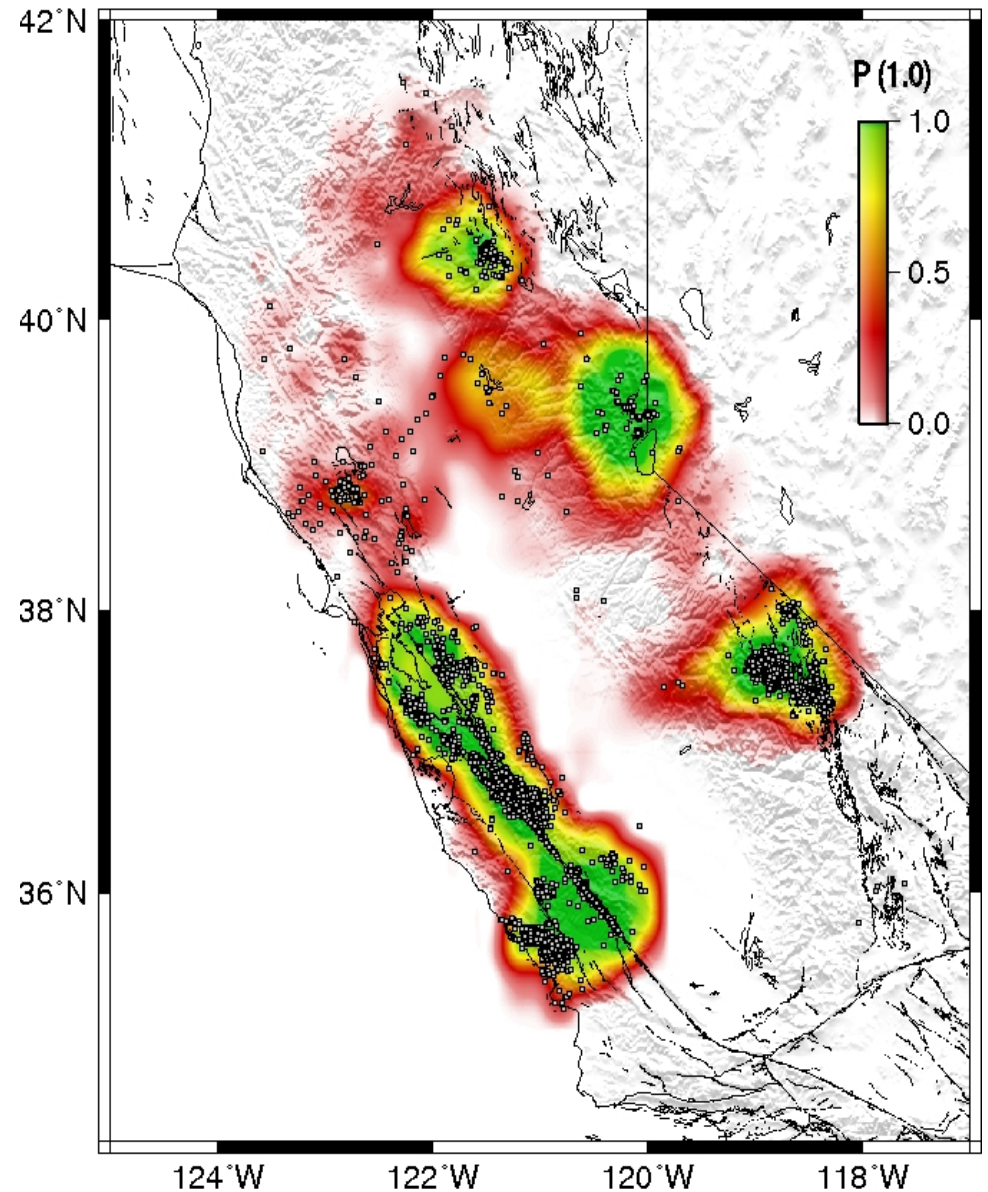
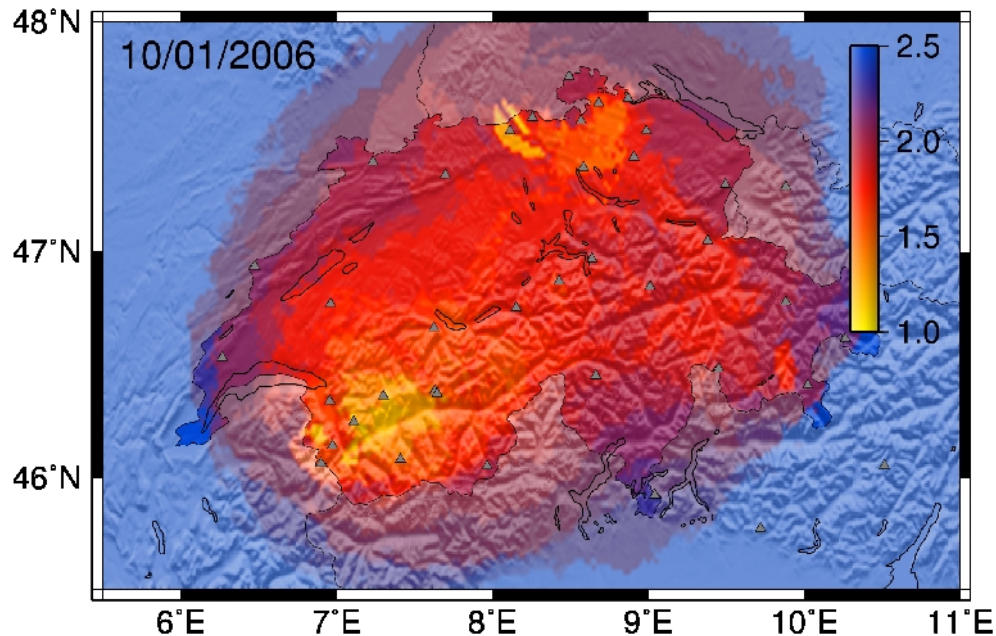


Other Networks

- Northern California
- Switzerland

In Progress:

- Friuli (Italy)



Webservice



SC/EC
an NSF+USGS center

HOME	PRODUCTS	ACKNOWLEDGMENTS	HELP
------	----------	-----------------	------

Network

SCSN

Date _____

2007-06-21

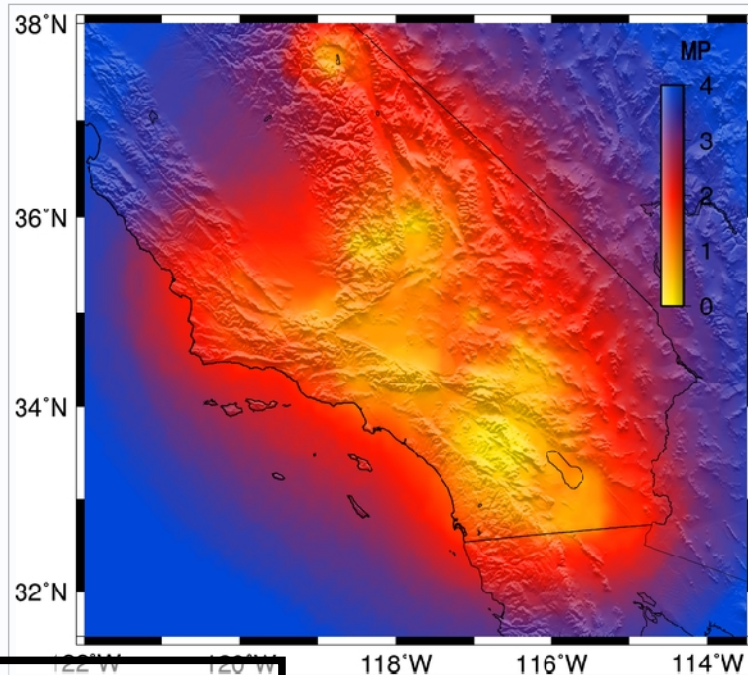
Show

Product

select product

Download

Completeness (M_p) for SCSN at 2007-06-21



completeness.usc.edu

[< earlier map](#) | [later map >](#)

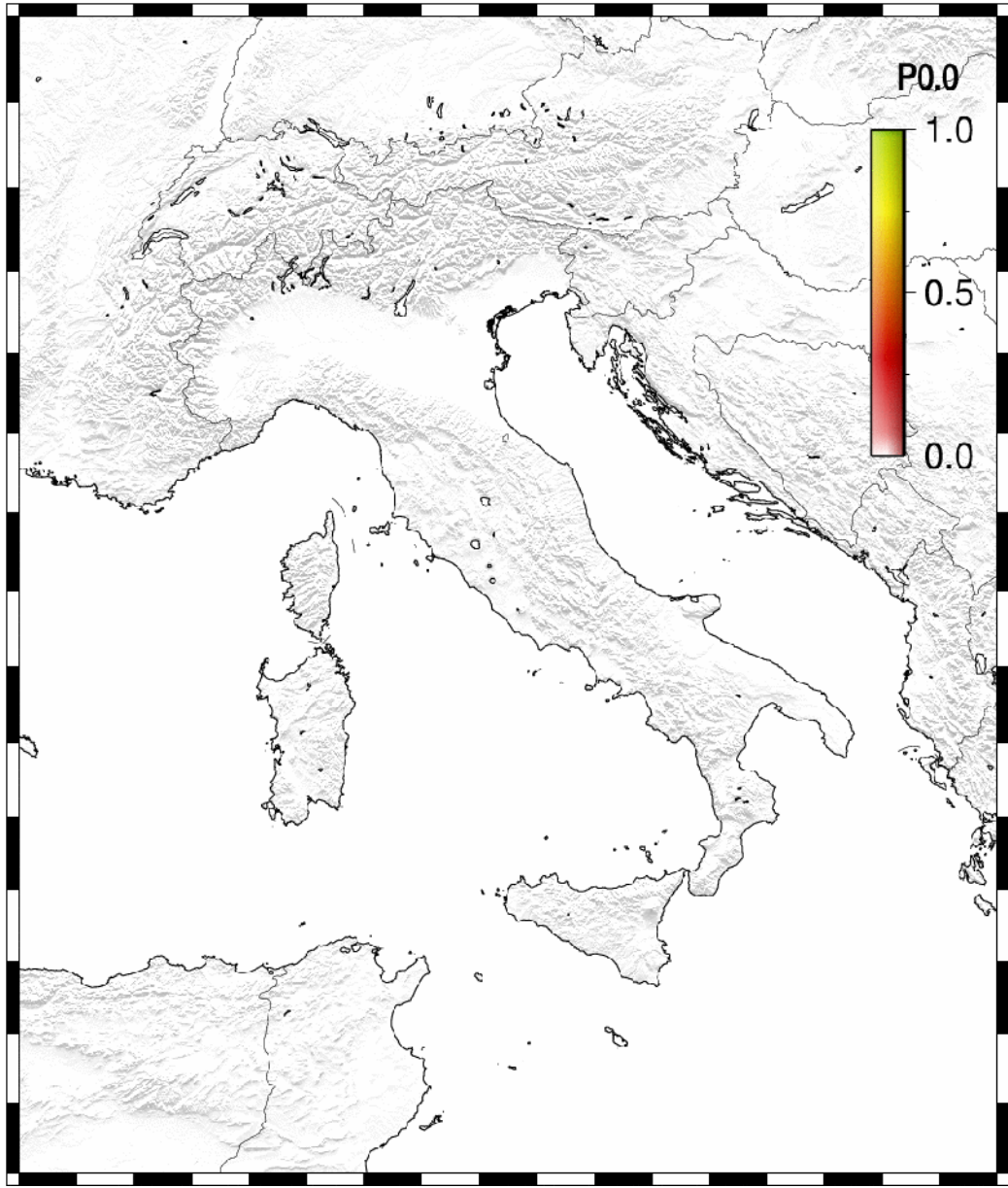
Done

Italy

INGV Network

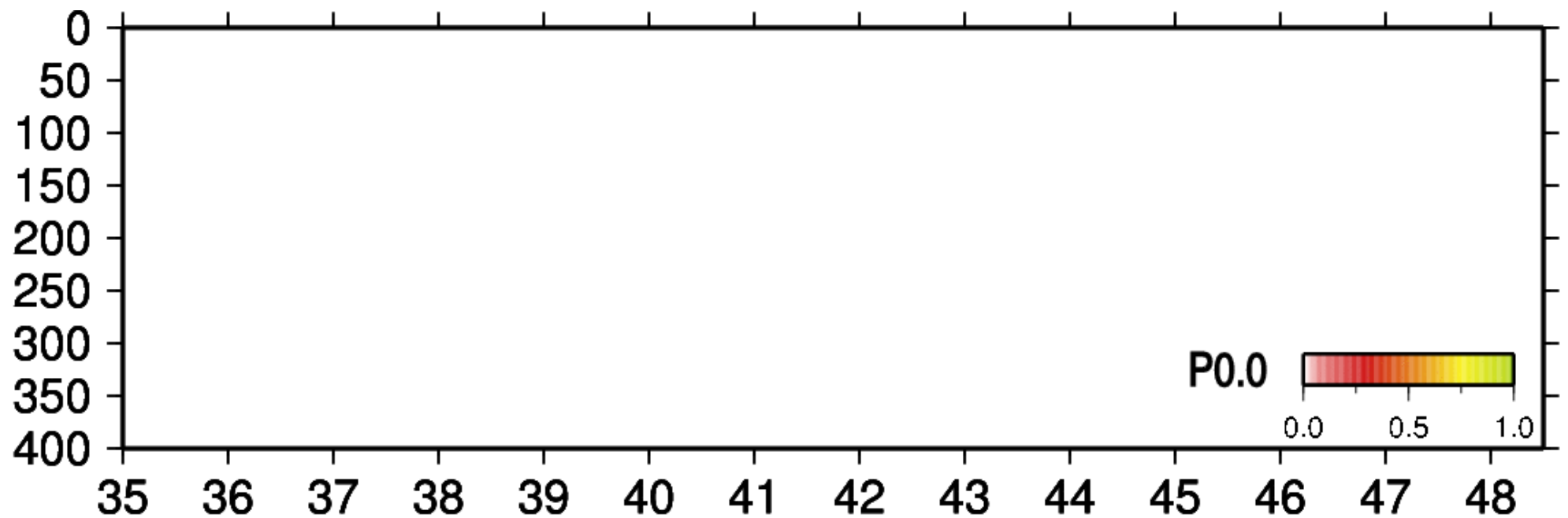
- List of stations
- On/Off-times derived from waveform files
- List of linktypes per station
- INGV earthquake catalog
- Magnitude definition used at INGV

Detection Probabilities

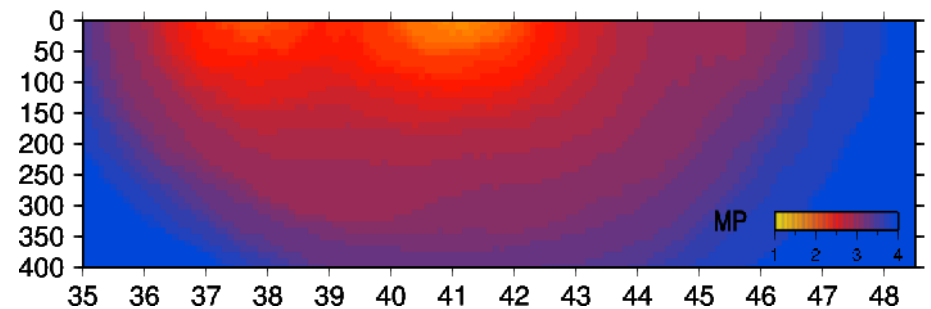
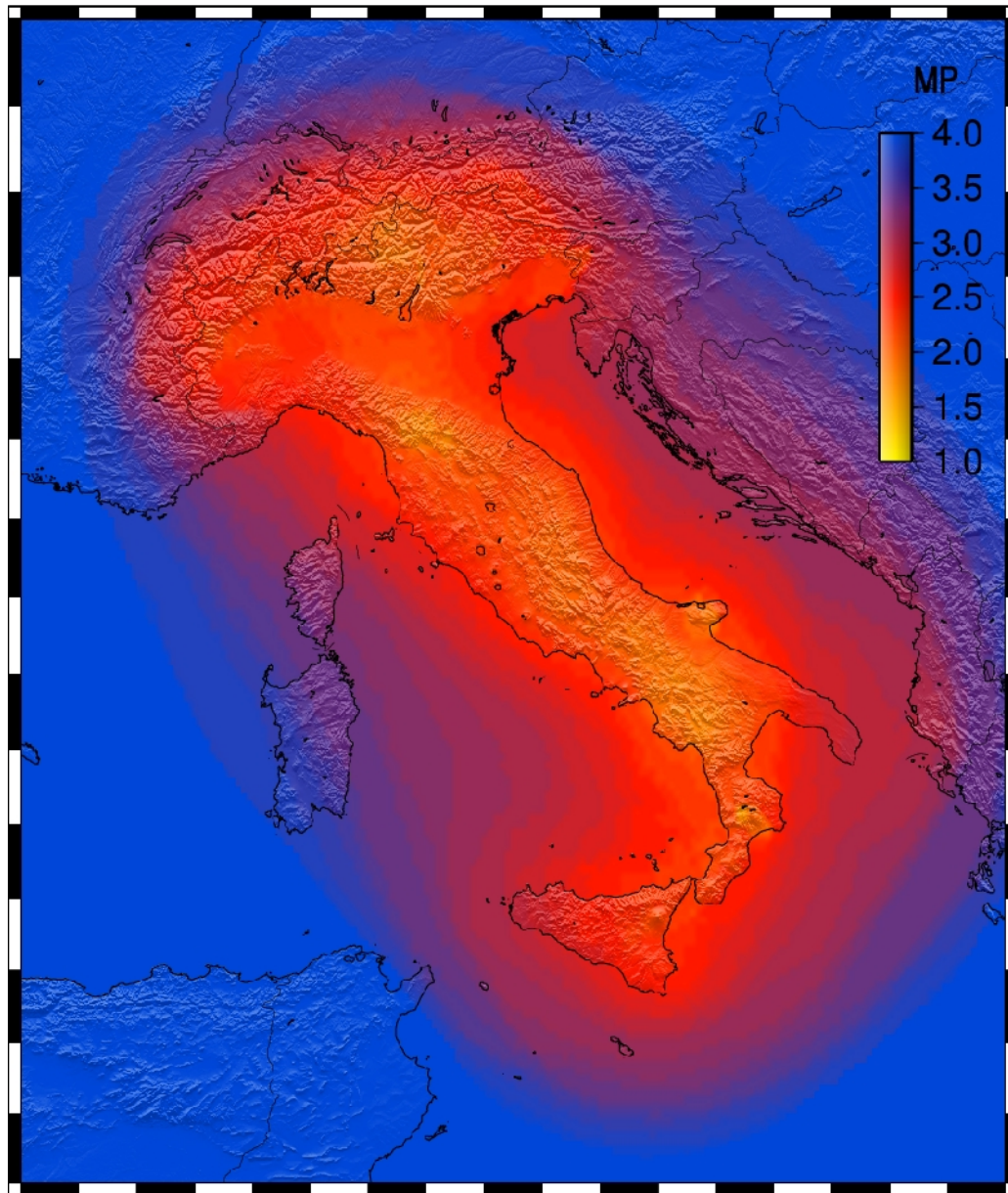


Detection with Depth

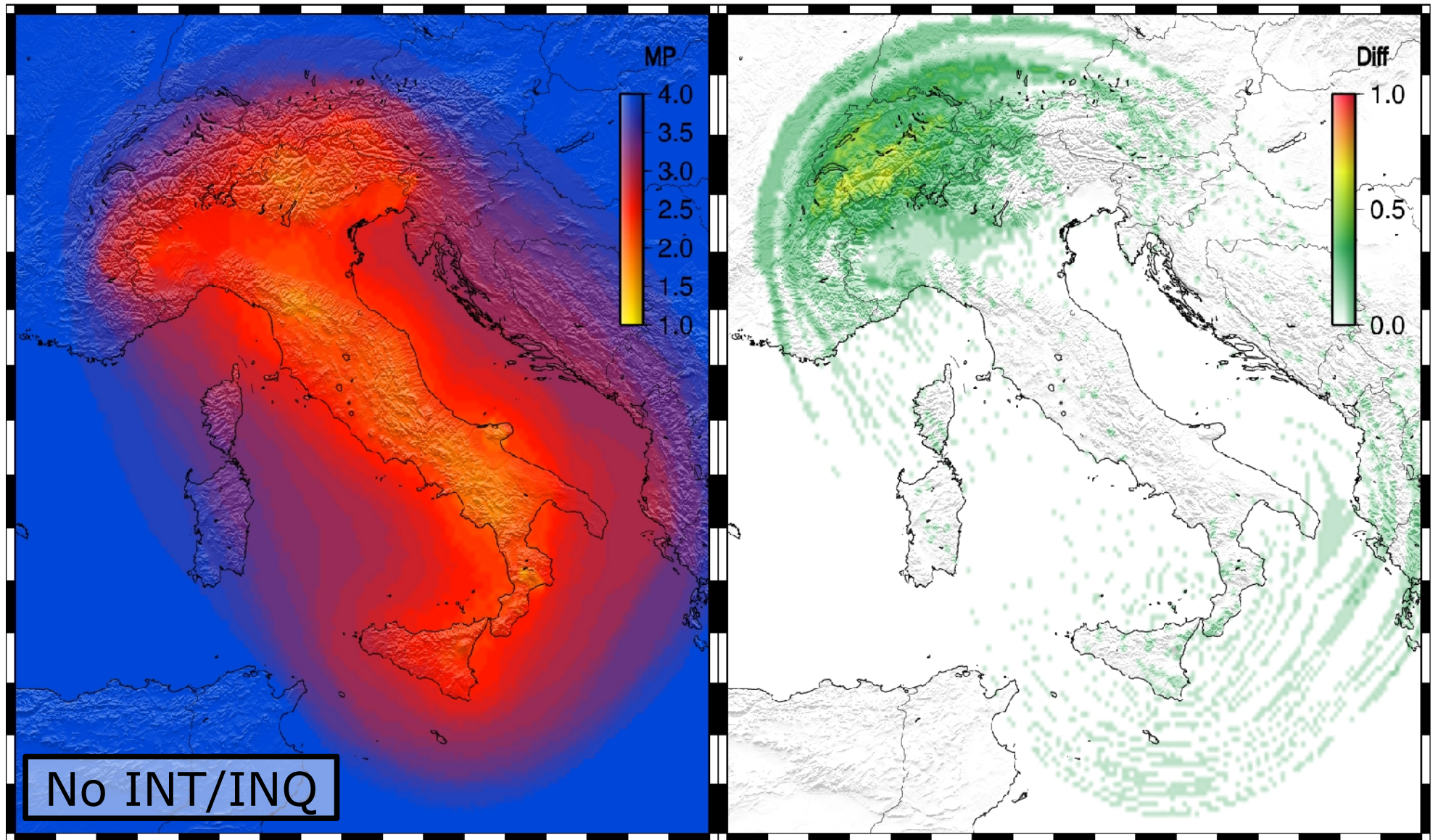
Along longitude 15E



Completeness



Scenarios



CSEP Testing Region Italy

Rationale

Target area: cover all of Italy

Testing area: extend 50-100km around target area

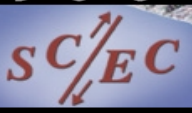
Collection area: extend further 50km around testing area

Completeness

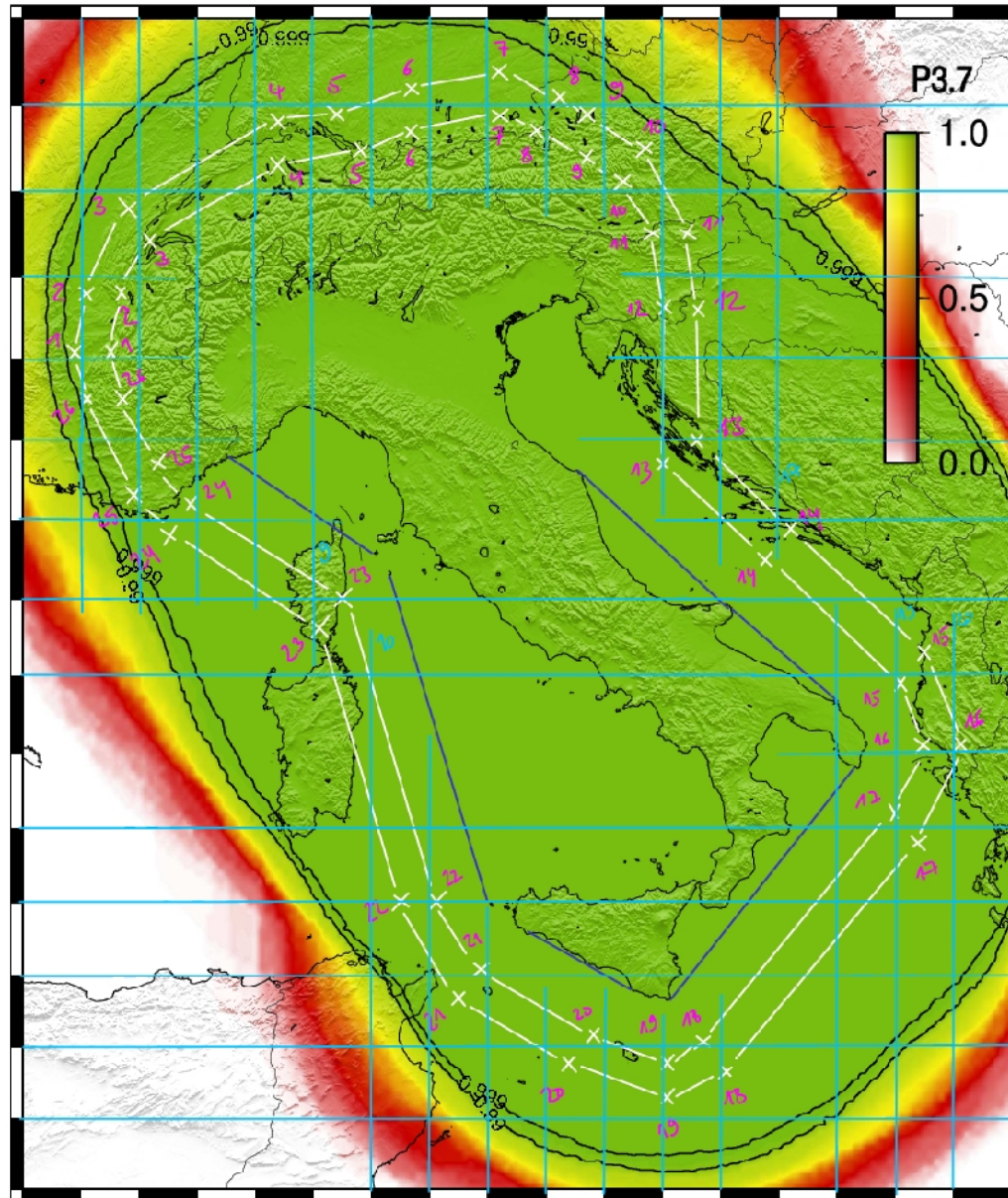
Target magnitude range is M4+

Testing area: 0.999 (99.9%) at M3.7+

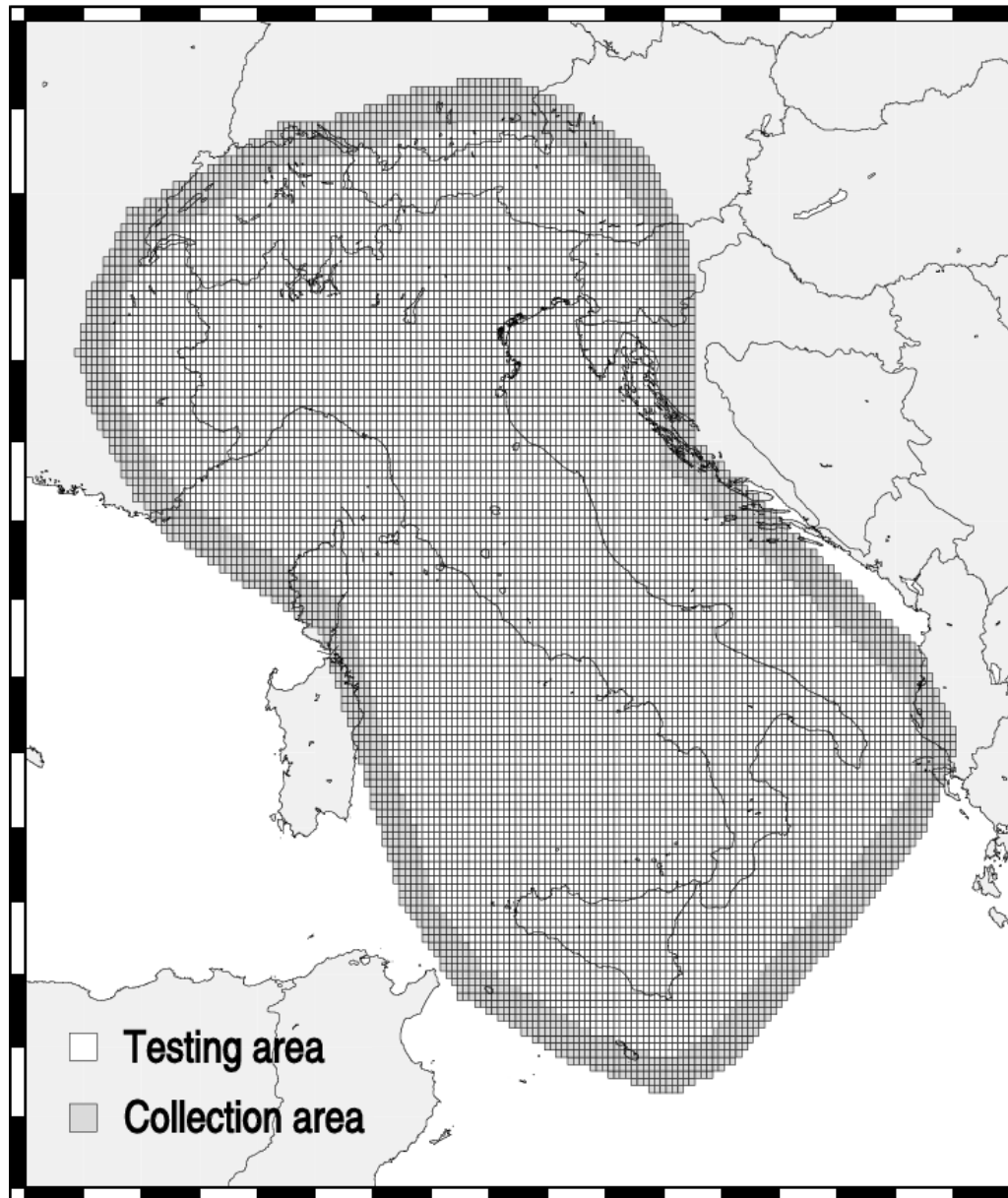
Collection area: 0.99 (99%) at M3.7+



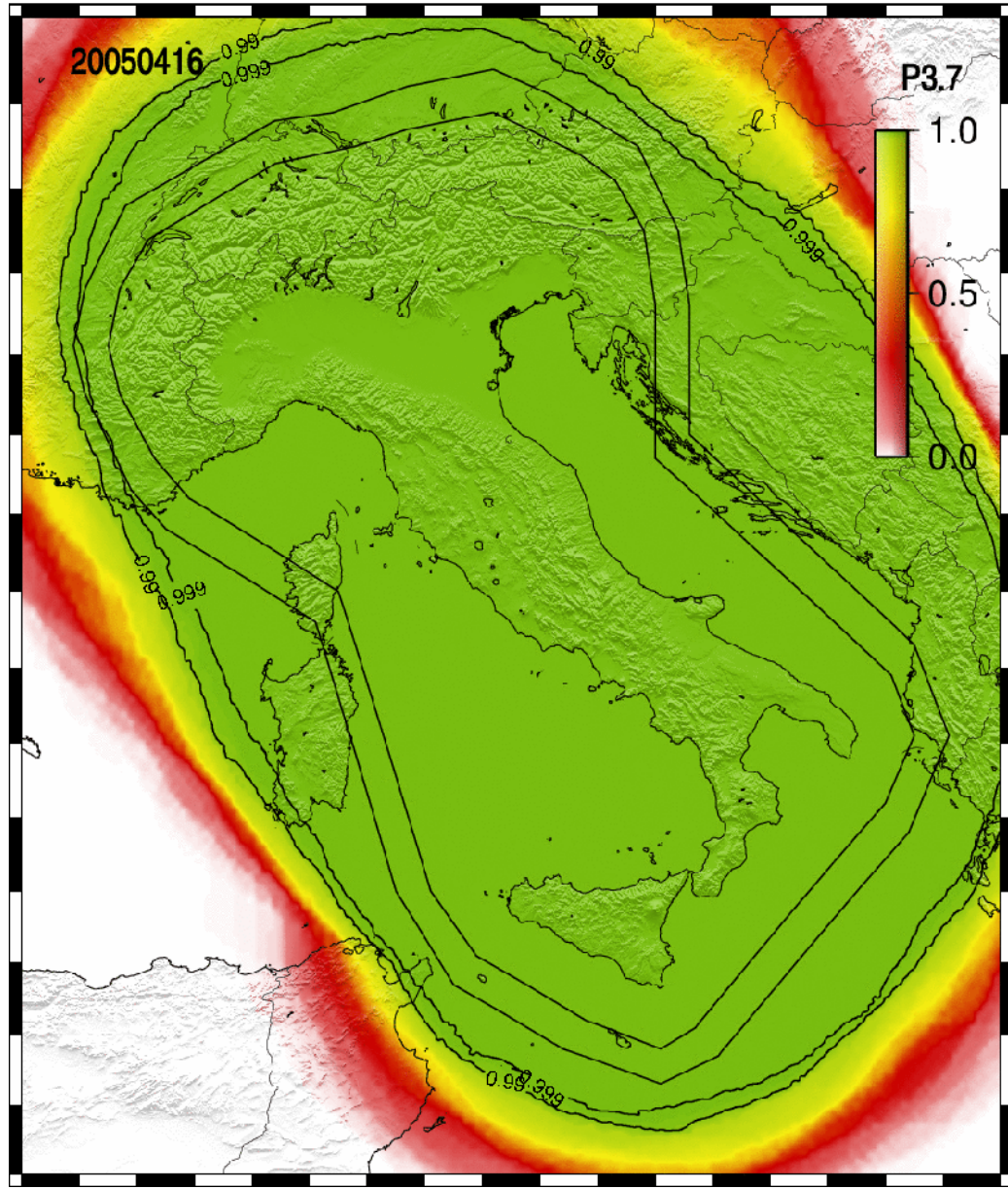
CSEP Testing Area



CSEP Testing Area



CSEP Testing Region Italy



Summary

New method for estimating completeness

PROS:

- No model assumption (Gutenberg-Richter distribution)
 - Volcanoes
- No averaging over space and time
 - Statement for a particular network configuration
- Full description of completeness changes over space/time
- More “complete” description (Prob. per magnitude)
- Works in low-seismicity areas
- Takes site conditions into account
- Takes localization procedure into account

CONS:

- Computationally more intensive than traditional methods

In Progress

- Investigate completeness of the JMA network
- Define testing area for CSEP
- Implement automatic catalog retrieval
- Set up the CSEP Testing Center in Japan

Thank You!

Visit our websites:

- www.cseptesting.org
- us.cseptesting.org
- relm.cseptesting.org
- completeness.usc.edu
- www.quakeml.org
- www.quakepy.org